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GEORGE BLAKE WALKER, M.INST.C.E.,

PRESIDENT OF THE INSTITUTION OF MINING ENGINEERS, 1918-1919.

TRANSACTIONS

OF

THE INSTITUTION

OF

MINING ENGINEERS.

VOL. LVI.—1918-1919.

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ERRATA.

Page 137, lines 10 and 11, "The President," etc., should be deleted.

,, 293, line 23, *for* "noxious" *read* "innocuous."

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CHARTER, BYE-LAWS, AND RULES

OF

THE INSTITUTION OF MINING ENGINEERS.

CHARTER.

GEORGE THE FIFTH by the Grace of God of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas, King, Defender of the Faith: To all to whom these Presents shall come Greeting:

WHEREAS the Voluntary Association or Institution now existing, and known as The Institution of Mining Engineers, hath petitioned Us for a Charter of Incorporation such as is in and by these Presents granted:

And whereas we are minded to comply with the prayer of such Petition:

NOW, THEREFORE, We, by virtue of Our Royal Prerogative in that behalf, and of all other powers enabling Us so to do, of Our Special Grace certain knowledge and mere motion do hereby, for Us, Our Heirs, and Successors, will, grant, direct, appoint, and declare to the said Voluntary Association or Institution as follows:—

1. The persons now Members of the said Voluntary Association or Institution known as The Institution of Mining Engineers, and all such persons as may hereafter become Members of the Body Corporate hereby constituted pursuant to or by virtue of the powers granted by these Presents, and their Successors, shall for ever hereafter be by virtue of these Presents one Body Corporate and Politic by the name of "The Institution of Mining Engineers," and by the same name shall have perpetual succession and a Common Seal, with power to break, alter, and make anew the said Seal from time to time at their will and pleasure, and by the same name shall and may implead, and be impleaded in all Courts, and in all manner of actions and suits, and shall have power to do all other matters and things incidental or appertaining to a Body Corporate.

2. We do also hereby, for Us, Our Heirs, and Successors, license, authorize and for ever hereafter enable The Institution of Mining Engineers hereby incorporated, or any person on its behalf, to acquire, for the purposes of the Institution, any lands, tenements or hereditaments whatsoever within Our United Kingdom of Great Britain and Ireland, not exceeding in the whole the annual value of Two Thousand Pounds (to be determined according to the value thereof at the time when the same are respectively acquired), and to hold the same in perpetuity and from time to time to grant, demise, alienate or otherwise dispose of the same or any part thereof.

3. And We do hereby also, for Us, Our Heirs, and Successors, give and grant Our License to any person or persons, and

any Body Politic or Corporate, to assure in perpetuity, or to demise to or for the benefit of The Institution of Mining Engineers any lands, tenements or hereditaments whatsoever, within Our United Kingdom of Great Britain and Ireland, so as the same do not exceed at any one time the annual value aforesaid.

4. The objects and purposes for which The Institution of Mining Engineers (hereinafter called "The Institution") is hereby constituted are:—The advancement of coal and iron-ore mining and allied industries; and the promotion of the acquisition of the knowledge necessary for the control and direction of mining operations in relation to stratified deposits.

5. The Institution shall not carry on any trade or business, or engage in any transactions with a view to the pecuniary gain or profit of the Members thereof. No Member shall have any personal claim on any property of the Institution or make any profit out of his Membership, except in the case of and as a salaried Officer of the Institution.

6. There shall be a Council of the Institution consisting of such number of Members, with such qualifications, and to be elected in such manner, and to hold office for such period, and on such terms as to re-election and otherwise, as the Bye-laws for the time being of the Institution shall direct.

7. Of the Members of the said Council of the Institution one shall be the President, and two or more shall be the Vice-Presidents of the Council. The said President and Vice-Presidents shall be elected in such manner, and shall hold office for such period, and on such terms as to re-election and otherwise, as the Bye-laws for the time being of the Institution shall direct.

8. The first President of the Council of the Institution shall be—

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The said Members of the Council, President, and Vice-Presidents, shall respectively hold office until the due election of their Successors in accordance with the Bye-laws of the Institution, but shall be respectively eligible, subject to such Bye-laws, for re-election if otherwise qualified.

9. The Institution shall have such Officers, with such functions, tenure, and terms of office, as the Bye-laws of the Institution may prescribe, and such other Officers and Servants as the Council of the Institution may from time to time appoint.

10. The government and control of the Institution and its affairs shall be vested in the Council subject to the provisions of these Presents and to the Bye-laws of the Institution. The business of the Council shall be conducted in such manner as the Bye-laws of the Institution may prescribe.

11. Unless and until the Bye-laws of the Institution shall otherwise provide there shall be five classes of Members of the Institution termed respectively Members, Associate Members, Honorary Members, Associates, and Students.

12. The qualifications, method and terms of admission, privileges and obligations, including liability to expulsion or suspension of Members of each of the said five classes respectively, shall be such as the Bye-laws for the time being of the Institution shall direct.

13. The Council shall have power to decide conclusively respecting each person proposed for or seeking admission as a Member of the Institution whether he has or has not fulfilled such conditions as are applicable to his case.

14. A Member may use after his name the initials "M.I.Min.E."; an Associate Member, "Assoc.M.I.Min.E."; an Honorary Member, "Hon.M.I.Min.E."; an Associate, "Assoc.I.Min.E."; and a Student, "Stud.I.Min.E."

15. All Members of the Institution shall, subject to any restrictions in the Bye-laws for the time being of the Institution contained, be entitled to be present and vote at General Meetings and take part in the discussion of business thereat.

16. The Council, or the majority of those Members thereof actually present and voting at any duly convened Meeting, shall have power from time to time to make such Bye-laws of the Institution as to them shall seem requisite and convenient for the regulation, government, and advantage of the Institution, its Members and property, and for the furtherance of the objects and purposes of the Institution, and from time to time revoke, alter, or amend any Bye-law or Bye-laws theretofore made so that the same be not repugnant to these Presents or to the Laws and Statutes of this Our Realm: Provided that no such Bye-law, revocation, alteration, or amendment shall take effect until the same has been submitted to and approved by a General Meeting of the Institution with respect to which notice has been given that such Bye-law, revocation, alteration, or amendment will be taken into consideration thereat, and has been allowed by the Lords of Our Privy Council of which allowance a Certificate under the hand of the Clerk of Our Privy Council shall be conclusive evidence.

17. The first Bye-laws to be made under these Presents shall be made by the Council, and approved by a General Meeting of the Institution, within the period of six months from the date of these Presents, unless the Lords of Our Privy Council shall see fit to extend such period, of which extension the Certificate of the Clerk of Our Privy Council shall be conclusive evidence.

18. Pending the making and approval of the Bye-laws to be made under these Presents, but no longer, the Articles and Bye-laws of the existing Voluntary Association or Institution known as The Institution of Mining Engineers shall be the Bye-laws of the Institution, and shall have effect as though the Institution, its Officers and Members had therein been referred to throughout in lieu of the said Voluntary Association or Institution, its Officers and Members.

19. The property and moneys of the said Voluntary Association or Institution known as The Institution of Mining Engineers shall from the date of these Presents become and be deemed to be the property and moneys of the Institution, and shall, as soon as may be, be formally transferred to the Institution or such person or persons on its behalf as the Bye-laws may prescribe.

20. And we do hereby, for Us, Our Heirs, and Successors, Grant and Declare that these Our Letters Patent, or the enrolment or exemplification thereof, shall be in all things good, firm, valid, and effectual, according to the true intent and meaning of the same, and shall be taken construed and adjudged in all Our Courts or elsewhere in the most favourable and beneficial sense and for the best advantage of the said Institution, any misrecital, non-recital, omission, defect, imperfection, matter or thing whatsoever notwithstanding.

IN WITNESS whereof We have caused these Our Letters to be made Patent.

WITNESS Ourself at Westminster, the ninth day of February, in the Year of our Lord one thousand nine hundred and fifteen, and in the fifth year of Our Reign.

BY WARRANT under the King's Sign Manual.

SEAL.

MUIR MACKENZIE.

BYE-LAWS.

I.—OBJECTS.

1.—The objects and purposes for which The Institution of Mining Engineers was constituted by Royal Charter in 1915 are :—The advancement of coal and iron-ore mining and allied industries, and the promotion of the acquisition of the knowledge necessary for the control and direction of mining operations in relation to stratified deposits.

II.—CONSTITUTION.

2.—The Institution of Mining Engineers shall consist of such Members, Associate Members, Honorary Members, Associates, and Students of the following Institutes as have been elected by the Council of the Institution in accordance with the Bye-laws. Such Institutes, hereinafter referred to as the "Federated Institutes," are :—

The North of England Institute of Mining and Mechanical Engineers (founded in 1852),
The Mining Institute of Scotland (founded in 1878),
The Manchester Geological and Mining Society (founded in 1838),
The Midland Institute of Mining, Civil, and Mechanical Engineers (founded in 1857),
The Midland Counties Institution of Engineers (founded in 1871),
The North Staffordshire Institute of Mining and Mechanical Engineers (founded in 1872), and
The South Staffordshire and Warwickshire Institute of Mining Engineers (founded in 1867),

and such other Institutes interested in mining as shall from time to time join the Institution.

3.—The affairs and business of the Institution shall be managed and controlled by the Council.

4.—The offices of the Institution shall be in London, or in such other place as shall be from time to time determined by resolution of the Council.

5.—Written applications from Societies or Institutes desirous of entering the Institution shall be made to the Council by the President of the applying Society or Institute, who shall furnish such information as may be desired by the Council.

III.—MEMBERSHIP.

6.—The membership shall consist of Members, Associate Members and Honorary Members, Associates, and Students, each of whom must be a member of one of the Federated Institutes.

(i) "Members" shall comprise every person who on the 12th day of January, 1916, was on the Institution Register as a Member of a Federated Institute. Every candidate for admission to the class of Members, or for transfer to that class subsequent to the said date, must be not less than 30 years of age, and must come within one of the following conditions :—

(*a*) He shall have been regularly educated and trained as a mining engineer, and for at least five years have held some responsible position in regard to, and at the time of his candidature be occupied in, practical mining; or
(*b*) He shall be a person holding a First Class Certificate of Competency under the Coal Mines Act; or
(*c*) He shall be, in the opinion of the Council, by reason of his position or attainments, a desirable person to become a Member.

(ii) "Associate Members" shall comprise every person who on the 12th day of January, 1916, was on the Institution Register as an Associate Member. Every candidate for admission to the class of Associate Members, or for transfer to that class subsequent to the said date, must be not less than 23 years of age, and must come within one of the following conditions :—

(*a*) He must be at the time of his candidature engaged in pursuits of a character leading up to the qualifications for membership; or
(*b*) He must be engaged in branches of engineering other than mining engineering; or
(*c*) He shall be, in the opinion of the Council, by reason of his position or attainments, a desirable person to become an Associate Member.

(iii) "Honorary Members" shall comprise every person who on the 12th day of January, 1916, was on the Institution Register as an Honorary Member. Persons elected subsequent to the said date shall have distinguished themselves by their attainments, or have contributed to the advancement of mining or other branches of technology, and shall be elected by the Council of the Institution.

(iv) "Associates" shall comprise every person who on the 12th day of January, 1916, was on the Institution Register as an Associate. Every candidate for admission to the class of Associates, or for transfer to that class, subsequent to the said date, must be not less than 21 years of age, and must be at the time of his candidature engaged in mining or its allied industries, and not eligible to belong to the class of Members or Associate Members.

(v) "Students" shall comprise every person who on the 12th day of January, 1916, was on the Institution Register as a Student. Every candidate for admission to the class of Student subsequent to the said date shall be a person who is qualifying himself for the profession of mining or any of its allied industries, and such person may continue as a Student until he attains the age of 23 years; but a Student may be raised to the class of Associate on attaining the age of 21 years, if properly qualified.

Recommendations for membership must be submitted in accordance with Form "A" in the Appendix. Recommendations for transfer from one class to another must be in accordance with Form "B" in the Appendix.

7.—Any Member, Associate Member, Honorary Member, Associate, or Student, having occasion to designate himself as belonging to the Institution, shall state the class to which he belongs according to the following abbreviated forms:—"M.I.Min.E.," "Assoc.M.I.Min.E.," "Hon.M.I.Min.E.," "Assoc.I.Min.E.," "Stud.I.Min.E."

No person shall adopt or describe himself by any other abbreviation to indicate the class to which he belongs than that provided for in this Bye-law for such members.

8.—The Federated Institutes shall elect their members of all classes according to their own Bye-laws, and the names of all members so elected shall, together with their qualifications, be submitted to the Council of the Institution. The Council shall elect from the list of names so submitted those whose qualifications comply with the Bye-laws of the Institution to be Members, Associate Members, Associates, or Students of the Institution, respectively as the Council shall think fit, and shall issue a certificate of membership (in accordance with Form "C" in the Appendix) to each person so elected, which shall remain the property of the Institution, and the Council shall have the right to call in such certificate after the holder has ceased to be a member of the Institution. Each person so elected shall sign the form of obligation on Form "A" in the Appendix. Notice of such election shall be sent to the Federated Institutes concerned.

9.—The Members, Associate Members, Honorary Members, Associates, and Students shall have notice of, and the privilege of attending, the Ordinary and Annual General Meetings, and shall receive all publications of the Institution. If any member (of whatsoever class) of any Federated Institute shall be in arrear in his payments to such Institute, he shall not be entitled to receive the publications and other privileges of the Institution until such arrears be paid to his Institute and the Calls in respect of such arrears paid to the Institution.

10.—Each person shall remain a member of the Institution only so long as he remains a member of one of the Federated Institutes, except in the case of Honorary Members who have been especially elected by the Council of the Institution.

11.—The Council shall have the right, by a majority of four-fifths of those present at a meeting of the Council, specially called for the purpose, and at which at least twenty Members of the Council are present, to expel from the Institution any Member, Associate Member, Honorary Member, Associate, or Student who may have committed any offence which, in the opinion of the Council, renders him unfit to be a member; and in case the Council shall be of opinion that the professional conduct of any Member, Associate Member, Honorary Member, Associate, or Student should become the subject of enquiry, with a view of ascertaining whether there are grounds for his expulsion, or in case twenty or more Members or Associate Members shall think fit to draw up and sign a proposal for the expulsion of a Member, Associate Member, Honorary Member, Associate, or Student on any ground whatsoever, and shall deliver the same to the Secretary to be laid before the Council for consideration, the Council shall make such enquiry as they may deem expedient; and if they do not find sufficient reason for expulsion, no entry of the enquiry shall be made on the minutes; but if the Council by a majority of at least four-fifths of those present at a meeting of the Council, specially summoned for the purpose, and at which at least twenty Members of the Council are present, do find good reason for expulsion of the Member, Associate Member, Honorary Member, Associate, or Student, on the ground that he has been guilty of improper conduct in any professional respect, they shall cause such person's name to be erased from the Register and thus expel him from the Institution. The Secretary shall give him notice according to Form "D" in the Appendix.

IV.—SUBSCRIPTIONS.

12.—Each of the Federated Institutes shall pay for each Member, Associate Member, Honorary Member (not being an Honorary Member of the Institution), Associate, and Student, such sum per annum (hereinafter referred to as "Call"), and in such instalment or instalments, as may be determined from time to time by resolution or resolutions of the Council. A person joining any of the Federated Institutes during the financial year of the Institution shall be entitled to all publications issued for that year, on his election by the Council of the Institution, provided that the instalment or instalments due on his behalf have been paid.

13.—Owners of collieries, engineering firms, employers of labour generally, and Institutions subscribing to the funds of any Federated Institute shall be entitled to receive a copy of the *Transactions* for each Call paid on their behalf.

V.—ELECTION OF OFFICERS AND COUNCIL.

14.—The Officers of the Institution, other than the Secretary or Secretaries, shall consist of Councillors elected annually by and out of the Members and Associate Members of each Federated Institute, who are Members or Associate Members of the Institution, in the proportion of one Councillor per forty Members or Associate Members thereof; of a President who shall be elected by the Council at their first meeting in each year, or whenever a vacancy occurs; and of Vice-Presidents elected by and from the Council at their first meeting in each year on behalf of each Institute, in the proportion of one Vice-President per two hundred Members or Associate Members thereof (but in any case each Institute shall be entitled to one Vice-President), who, with the Secretaries of the Federated Institutes and the Honorary Secretary (if appointed) and the Secretary of the Institution, shall form the Council. All Presidents on retiring from that office shall be *ex-officio* Vice-Presidents so long as they continue Members or Associate Members of the Institution.

15.—The office of a Member of the Council will be vacated if he ceases to be a Member or an Associate Member of the Institution, in which case, or in the case of the decease, expulsion, or resignation of any Member of the Council, the Council of the Federated Institute of which that member was a representative shall elect another to fill the vacancy for the unexpired period.

The Members of Council shall hold office for a period of one year, dating from the Annual General Meeting in each year.

VI.—DUTIES OF OFFICERS AND COUNCIL.

16.—The Council shall represent the Institution and shall act in its name; they shall transact all business and examine accounts, authorize payments, and may invest or use the funds in such manner as they may from time to time think fit, in accordance with the Bye-laws and Rules of the Institution.

17.—The meetings of the Council shall be called by circular-letter, issued to all the members at least seven days previously, accompanied by an agenda-paper, stating the nature of the business to be transacted. In the case of special meetings of the Council, at least fourteen days' previous notice shall be given.

18.—At meetings of the Council six shall form a quorum, unless otherwise provided for.

19.—The Council may appoint committees, consisting of members of the Institution, for the purpose of transacting any particular business, or of investigating any specific subject connected with the objects of the Institution. In appointing such committees, the Council shall nominate one of the members as Chairman, who shall convene the meetings of the committee. The President shall be an *ex-officio* member of all committees.

20.—The President shall take the chair at all meetings of the Institution and of the Council at which he may be present.

21.—In the absence of the President, it shall be the duty of the senior Vice-President present to preside at the meetings of the Institution. In case of the absence of the President and of all the Vice-Presidents, the meeting may elect any Member of Council, or in case of their absence any Member or Associate Member of the Institution, to take the chair at the meeting.

22.—The Council shall appoint one or more Secretaries. The duties and salary of the Secretary or Secretaries shall be fixed and may be varied from time to time by the Council.

23.—A Treasurer shall be appointed annually by the Council at their first meeting in each year. All monies belonging to the Institution shall be received by him, and shall be paid into a bank or banks, as may be determined from time to time by the Council.

24.—The accounts of the Treasurer and the financial statement of the Council shall be audited and examined by a chartered accountant, appointed each year by the members at the Annual General Meeting. The Auditor shall have access at all reasonable times to the accounts of the pecuniary transactions of the Institution; and he shall verify and sign the annual statement of the accounts before it is submitted by the Council to the Annual General Meeting, and state that he has examined the securities. The Institution securities shall be lodged with the Institution bankers.

VII.—General Meetings.

25.—At least two Ordinary General Meetings shall be held during the year, one in May or June and the other in September, or as the Council may determine; and the General Meeting in the month of September shall be the Annual General Meeting, at which a report of the proceedings, and an abstract of the accounts of the previous year ended July 31st, shall be presented by the Council. Each member on the Register of the Institution shall receive at least seven days' notice of such meetings.

VIII.—Publications.

26.—The publications of the Institution shall consist of the reports of the meetings of the Institution and of the meetings of the Federated Institutes, and abstracts of patents and other publications relating to mining and allied industries.

The following shall be deemed unsuitable, and shall be refused:—

(*a*) Papers containing advertising matter.
(*b*) Papers consisting largely of matter already printed in the English language.
(*c*) Papers consisting largely of matter foreign to the objects of the Institution or Federated Institutes.
(*d*) Papers containing matter the publication of which may be deemed injurious to the interests of the Institution or of any Federated Institute.

IX.—Property.

27.—The surplus funds may, after resolution of the Council, be invested, in the name of the Institution or in the names of Trustees, in such securities as are allowed for investment by trustees, in the purchase of land, or in the purchase, erection, alteration, or furnishing of buildings for the use of the Institution.

28.—Societies or members who may have ceased their connexion with the Institution shall have no claim to participate in any of its properties.

Under no pretence whatever shall the property and effects, or the income or revenue of the Institution, derived from voluntary contributions or otherwise howsoever, be applied in making any dividend, gift, division, or bonus, unto or between any of the members; and no proposition in contravention thereof shall be entertained by the Council, or by any meeting, whether general or special, of the members of the Institution.

X.—Alteration of Bye-laws.

29.—No alteration shall be made in the Bye-laws of the Institution, except at a *Special Meeting* of the Council called for that purpose, and the particulars of every such proposed alteration shall be notified at their previous meeting, and inserted in the minutes, and shall be sent to all Members of Council at least fourteen days previous to such Special Meeting; and the Council or the majority of those present and voting at such Special Meeting shall have power to adopt any modification of such proposed alteration of the Bye-laws, provided that no such Bye-law, revocation, alteration, or amendment shall take effect until the same has been submitted to and approved by a majority of the votes of the Members and Associate Members present at a General Meeting of the Institution with respect to which notice has been given that such Bye-law, revocation, alteration, or amendment will be taken into consideration thereat, and have been allowed by the Lords of His Majesty's Privy Council, of which allowance a certificate under the hand of the Clerk of the said Council shall be conclusive evidence.

XI.—Alteration of Rules.

30.—The Council may from time to time make such Rules for the better regulation of meetings of the Institution and of the Council, for the conduct of the election of its officers, and for such other matters and purposes as they may desire, and may from time to time take from, add to, or vary such Rules: provided always that such Rules shall be made, rescinded, or varied, by the votes of three-fourths of such Members of the Council as are present and voting at a meeting of the Council specially convened with notice of this object, and at which meeting there shall be present not less than twenty of the Members of the Council, which Rules or alterations shall be submitted to an Ordinary or to a Special General Meeting of the Institution, and shall only come into operation when and in the form adopted at such meeting by a majority of the votes of the Members and Associate Members then present and voting; provided further that nothing in such Rules shall violate the provisions of the Charter and Bye-laws of the Institution, and they shall only be made for the better carrying out of the instructions laid down by such Charter and Bye-laws.

XII.—Seal.

31.—The Common Seal shall not be affixed to any document except by resolution of the Council, and in the presence of two Members of the Council, and every such document shall be signed by the two Members of the Council in whose presence the Seal is affixed, and countersigned by the Secretary. The keys of the Seal shall be kept by the President of the Council and Secretary respectively, or by such other person or persons as may be appointed by the Council for that purpose.

XIII.—Enemy Alien Members.

32.—In the event of a state of war existing between the United Kingdom and any other country or State, all Honorary Members, Members, Associate Members, Associates, or Students, who shall be subjects of such enemy country or State, shall forthwith cease to be Honorary Members, Members, Associate Members, Associates, or Students, of the Institution, but they may be eligible for re-election after the war in the usual manner.

RULES.

I.—Council.

1.—There shall be at least three ordinary meetings of the Council in each year, two of which shall be held prior to but on the same day as the Ordinary or Annual General Meetings of the members.

2.—The order in which business shall be taken at the Ordinary and Annual General Meetings may be from time to time decided by the Council.

3.—Every question shall be decided at the meetings of the Council or Committees by the votes of the majority of the members present, except in cases otherwise provided for. In case of equal voting, the President, or other member presiding in his absence, shall have a second or casting vote.

4.—Members of Council shall have the right to vote by proxy in the election of Members, Associate Members, Honorary Members, Associates, and Students. A proxy form shall be issued with such notice of meeting for the use of Members of Council who may not be able to attend.

5.—A special meeting of the Council shall be called whenever the President may think fit, or upon a requisition to the Secretary of the Institution signed by twenty or more of its members, or by the Council of any of the Federated Institutes. The business transacted at a special meeting of the Council shall be confined to that specified in the notice convening it.

6.—The Council may communicate with the Government in cases of contemplated or existing legislation of a character affecting the interests of mining engineering or its allied industries.

7.—The Council shall decide or shall suitably delegate its authority to decide upon the publication of any communications.

8.—The minutes of the Council's proceedings shall at all times be open to the inspection of the Members and Associate Members.

9.—All payments on behalf of the Institution, when sanctioned by the Finance Committee, shall be made by cheques signed by two members of the Committee and countersigned by the Secretary. All payments so made shall be reported to the Council.

II.—SECRETARY.

10.—The Secretary shall summon and attend all meetings of the Council, and the Ordinary and Annual General Meetings of the Institution, and shall record the proceedings in the minute-book. He shall direct the administrative and scientific publications of the Institution. He shall have charge of and conduct all correspondence relative to the business and proceedings of the Institution, and of all committees where necessary, and shall prepare and issue all circulars to the members.

He shall have charge of the Library, arrange for the collection of the calls of members, the preparation of the accounts of the expenditure of the funds, and present all accounts to the Council for inspection and approval. He shall also engage all persons employed under him, and shall generally conduct the ordinary business of the Institution.

III.—PUBLICATIONS.

11.—Discussion may be invited on any paper published by the Institution, at meetings of any of the Federated Institutes, at which the writer of the paper may be invited to attend. Any report of such discussion, however, shall in all cases be submitted to the writer of the paper before publication, and he may append a reply at the end of the report.

12.—The Secretary of the Institution shall be responsible for the editing of the *Transactions* as a whole, for the editing of the reports of the meetings of the Institution and of the Federated Institutes, and for the miscellaneous portion. The Secretary of each Federated Institute shall prepare and edit all papers and discussions of such Institute, and promptly forward them to the Secretary of the Institution, who shall submit proofs to the Secretary of the Federated Institute before publication.

13.—A paper for reading at any of the meetings of the Institution shall be sent to the Secretary at least six weeks before the meeting in question. The Secretary may refer a paper back to the author for compression or alteration, or, in case the matter be deemed suitable, but objection be taken to the mode of expression thereof, he may refer it back to the author for amendment in this respect. If the author and the Secretary cannot agree as to the suitability of the paper, the Secretary shall submit it to two Members of the Publications Committee. If both of these approve or reject it, their decision shall be final, but if their views differ, the paper shall be referred to the President of the Institution, whose decision shall be final.

A paper that has been submitted to and approved by the Council of a Federated Institute shall be sent to the Secretary of the Institution at least a fortnight before the date of the meeting at which it is intended to be read, together with any drawings or illustrations which may be required to accompany it. If desired by the Secretary of the Federated Institute, the Secretary of the Institution will then have the paper printed in galley form for distribution at the meeting. After the meeting, the paper, revised if necessary by the Secretary in question, shall be returned to the Secretary of the Institution in its final form, ready for setting up in pages. If the Secretary of the Institution, at any time, considers the paper unsuitable for appearance in the *Transactions*, he shall notify the Secretary of the Federated Institute, and shall refer it to two Members of the Publications Committee, excluding the Secretary and member or members representing the Institute from which the paper proceeds. If, in the unanimous opinion of these members, the paper is unsuitable for insertion in the *Transactions*, it shall not appear therein, but if their views differ, the paper shall be referred to the President of the Institution, whose decision shall be final.

14.—Any discussion taking place at meetings of the Institution shall be reported by a competent reporter. The proof of each speaker's remarks in the discussion shall be sent to him by the Secretary of the Institution with an intimation that, if not returned corrected within seven days, it will be considered as correct, and the Secretary shall then edit the revised discussion.

15.—The Federated Institutes shall make their own arrangements for reporting the discussions at their meetings and for the correction of the reports of the speakers. The Secretary of each Federated Institute shall forward a clear transcript of the discussion, edited by him, to the Secretary of the Institution for printing. Two galley-proofs shall be sent to the Secretary of the Federated Institute for correction, one of which shall be returned ready for printing within seven days of receipt by him, failing which it shall be considered correct.

16.—The Publications Committee may accept communications from persons who are not members of the Institution.

17.—Invitations may be sent by the Secretary to any person whose presence at discussions shall be thought desirable by the Council, and persons so invited shall be permitted to read papers and take part in the proceedings and discussions.

18.—A paper in course of publication cannot be withdrawn by the writer, without the permission of the Publications Committee.

19.—The copyright of all papers accepted for publication in the *Transactions* shall become vested in the Institution, and such communications shall not be published for sale or otherwise without the written permission of the Council. The Council shall have power, however, to make any arrangement that they may think proper with the author on first accepting his paper.

20.—Thirty copies of each paper and the accompanying discussion shall be presented to the writer free of cost. He may also obtain additional copies (not exceeding one hundred) upon payment of the cost to the Institution, by an application attached to his paper. If more than one hundred extra copies are required, these shall only be supplied by the express permission of the Finance and Publications Committee. These copies, except by special permission of the Council, must be unaltered copies of the paper and accompanying discussion as appearing in the publications of the Institution, and the copy shall state that it is an "Excerpt from the *Transactions* of The Institution of Mining Engineers."

21.—The Federated Institutes may receive copies of their own portion of the publications in respect of such of their members as do not become members of the Institution, and shall pay 10s. per annum in respect of every copy so supplied; and similar copies for exchange (but not for sale) shall be paid for at cost price.

22.—A list of the members, with their last-known addresses, and indicating the Federated Institute to which they belong, shall be printed annually in the publications of the Institution.

23.—The publications of the Institution may be sold at such prices as may be determined from time to time by the Council.

24.—The Institution, as a body, is not responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at the meetings of the Institution or of the Federated Institutes.

IV.—MEDALS AND OTHER REWARDS.

25.—The Council, if they think fit in any year, may award medals or other rewards to the author or authors of papers published in the *Transactions*, or to persons who have distinguished themselves by their contribution to the advancement of mining and other branches of technology.

V.—PROPERTY.

26.—The Institution may form a collection of papers, books, models, etc.

APPENDIX,
CONTAINING FORMS REFERRED TO IN THE BYE-LAWS.

FORM "A."—FOR THE NOMINATION OF MEMBERS, ASSOCIATE MEMBERS, ASSOCIATES, AND STUDENTS.

THE INSTITUTION OF MINING ENGINEERS.
39, Victoria Street, Westminster, London, S.W. 1.

(Established July 1st, 1889; Incorporated by Royal Charter February 9th, 1915)

(The Qualifications of the Candidate must be stated in accordance with the spirit of Bye-law 6, which is printed on the back of this Form)

Mr. ....
Designation or Occupation ....
Address ....
born on the .... **day of** ...., **19**........, **being desirous of becoming a** .... **of The Institution of Mining Engineers, and having been duly elected a** .... **of the** ....
....
is proposed by the Council of the said Federated Institute as a proper person to belong to the Institution, because
....
....
....
....
....
....
....
....

Christian Name, Surname, and Address to be given in full.

State Class of Membership.

State Name of Federated Institute.

State briefly:
(a) Candidate's training, and date and number of Home Office Certificate (if any);
(b) Professional experience; and
(c) Present occupation.

UNDERTAKING TO BE SIGNED BY THE CANDIDATE.

I, the undersigned, do hereby promise that, in the event of my election, I will be governed by the Royal Charter, Bye-laws, and Rules of the Institution for the time being, or as they may hereafter be altered, amended, or enlarged under the powers of the said Royal Charter; and that I will promote the objects of the Institution as far as may be in my power, and will not aid in any unauthorized publication of the proceedings, and will attend the meetings thereof as often as I conveniently can; provided that whenever I shall signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period to my local Institute) cease to belong to the Institution.

Signed ....
Dated this .... **day of** ...., **19**........

On the above grounds the Council of the ....
....
recommend Mr. ....**'s election as a**
....

Signed on behalf of the Council of the ....
....

Secretary.

The Council of The Institution of Mining Engineers, having considered the above recommendation, hereby elect Mr. ....
a .... of the Institution.

Signed .... Chairman.

Date ....

Secretary of member's local Institute advised of election on ....

FORM "B."—FOR THE TRANSFER OF MEMBERS.

THE INSTITUTION OF MINING ENGINEERS.

39, Victoria Street, Westminster, London, S.W. 1.

(Established July 1st, 1889; Incorporated by Royal Charter February 9th, 1915)

(The Qualifications of the Candidate must be stated in accordance with the spirit of Bye-law 6, which is printed on the back of this Form)

Mr. ....
Designation or Occupation ....
Address ....
born on the .... day of ...., 19........,

Christian Name, Surname, and Address to be given in full.

being desirous of being transferred from the Class of ....
to the Class of ...., is proposed by the Council of the....................

State class of Membership.

....
as a proper person to become a... .... of the Institution, because

State Name of Federated Institute.

....
....
....
....
....
....
....
....
....
....

State briefly:
(a) Candidate's training, and date and number of Home Office Certificate (if any);
(b) Professional experience; and
(c) Present occupation.

UNDERTAKING TO BE SIGNED BY THE CANDIDATE.

I, the undersigned, do hereby promise that, in the event of my transfer, I will be governed by the Royal Charter, Bye-laws and Rules of the Institution for the time being, or as they may hereafter be altered, amended, or enlarged under the powers of the said Royal Charter; and that I will promote the objects of the Institution as far as may be in my power, and will not aid in any unauthorized publication of the proceedings, and will attend the meetings thereof as often as I conveniently can; provided that whenever I shall signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears whch may be due by me at that period to my local Institute) cease to belong to the Institution.

Signed ....
Dated this .... day of ...., 19........

On the above grounds the Council of the...
....
recommend Mr. ....'s transfer to
the Class of ....

Signed on behalf of the Council of the ....
....

Secretary.

The Council of The Institution of Mining Engineers, having considered the above recommendation, hereby elect Mr. ....
a .... of the Institution.

Signed .... Chairman.

Date ....

Secretary of member's local Institute advised of transfer on ....

FORM "C."—CERTIFICATE OF ELECTION.

THE INSTITUTION OF MINING ENGINEERS.
Established July 1st, 1889.
Incorporated by Royal Charter February 9th, 1915.

These are to Certify that

....

....

A .... of the

....

was elected a .... of

The Institution of Mining Engineers

at a Meeting of the Council of the Institution held on the .... day of ...., 19......

Witness our Hands and Seal this .... day of ...., 19.........

SEAL.

.... *President.*

.... *Hon. Secretary.*

.... *Secretary.*

FORM "D."—FOR THE EXPULSION OF MEMBERS.

THE INSTITUTION OF MINING ENGINEERS.
39, Victoria Street, Westminster, London, S.W. 1.
(Established July 1st, 1889; Incorporated by Royal Charter February 9th, 1915)

..............., 19........

Sir,

I am directed by the Council of The Institution of Mining Engineers to inform you that by a Resolution passed at a Special Meeting of the Council on the....................of......................................they have, acting under the powers conferred upon them by Bye-law 11 of the Institution, ordered your name to be erased from the Register, and have declared you to be no longer a...of the Institution.

I am, Sir, etc.,

....

Secretary.

THE INSTITUTION OF MINING ENGINEERS

SUBJECTS FOR PAPERS.

The Council of The Institution of Mining Engineers invite original communications on the subjects enumerated in the following list, together with other questions which are of interest to mining engineers.

Boiler explosions.
Boreholes and prospecting, including methods of boring.
Brickmaking by machinery.
Brine-pumping.
Canals, inland navigation, and the canalization of rivers.
Coal-getting by machinery.
Coal-washing machinery.
Coke manufacture and the recovery of bye-products.
Colliery leases, and limited liability companies.
Compressed air as a motive power.
Corrosive action of mine water on pumps, etc.
Descriptions of coalfields and other mineral deposits.
Distillation of oil-shales.
Duration of coalfields of the world.
Electric mining lamps.
Electricity and its applications in mines.
Engine-counters and speed-recorders.
Explosions in mines.
Explosives used in mines.
Faults and veins.
Fuels and fluxes.
Gas-, oil-, and petroleum-engines.
Gas-producers and gaseous fuel and illuminants.
Geology and mineralogy.
Haulage in mines.
Industrial assurance.
Inspection of mines.
Laws of mining and other concessions.
Lead-smelting.
Light railways.
Lubricating value of grease and oils.
Lubrication of trams and tubs.
Maintenance of canals in mining districts.
Manufacture of fuel-briquettes.
Mechanical ventilation of mines, and efficiency of the various classes of ventilators.
Mining of mineral deposits.
Natural gas: its conveyance and uses.
Occurrence of mineral ores, etc.
Ore-sampling and sampling machines.
Petroleum-deposits.
Preservation of timber.
Prevention of overwinding and accidents in shafts.
Pumping machinery.
Quarries and methods of quarrying.
Rescue-work.
Rock-drills.
Safety-lamps.
Screening, sorting, and cleaning of coal.
Shipping and discharge of coal-cargoes.
Sinking, coffering, and tubbing of shafts.
Spontaneous ignition of coal and coal-seams.
Steam-condensation arrangements.
Steam-power plants.
Submarine coal-mining.
Subsidences caused by mining operations.
Surface-arrangements at mines.
Surveying and surveying instruments.
Transport on roads.
Tunnelling methods and appliances.
Underground conveyors.
Utilization of dust and refuse-coal.
Ventilation of coal-cargoes.
Water as a motive-power in mines.
Water-incrustations in boilers, pumps, etc.
Water-tube boilers.
Watering coal-dust.
Winding-arrangements at mines.
Winning and working of mines at great depths.

The Council, if they think fit in any year, may award medals or other rewards to the author or authors of papers published in the *Transactions*, or to persons who have distinguished themselves by their contribution to the advancement of mining and other branches of technology.

TRANSACTIONS
OF
THE INSTITUTION
OF
MINING ENGINEERS.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
AUGUST 10TH, 1918.

MR. FRANK COULSON, PAST-PRESIDENT, IN THE CHAIR.

Mr. **JOHN SIMPSON** was unanimously re-elected President for the ensuing year.

PRESENTATION OF G. C. GREENWELL MEDALS.

The **CHAIRMAN** (Mr. Frank Coulson) presented a G. C. Greenwell Silver Medal (which had been awarded to the late Mr. Simon Tate) to Mr. W. O. Tate for his paper on " Further Notes on Safety-lamps." He also presented a similar medal to Mr. F. C. Lee for his paper entitled " Some Practical Notes on the Economical Use of Timber in Coal-Mines."

DISCUSSION OF MR. GEORGE RAW'S " NOTES ON THE OVERHEAD KŒPE WINDING PLANT AT PLENMELLER COLLIERY, HALTWHISTLE, NORTHUMBERLAND."*

Mr. A. **HANLEY** (Sheffield) wrote: With regard to rope adjustment, it seems to me that the principle of the extension-carriage might be applied to the guide-pulley, by placing the latter on a pair of vertical standards. This, where possible, would do away with the necessity for cage-chain adjustment-links, and would probably allow in most cases sufficient rope for the recappings. In the author's plant pulley friction is automatically provided for, and his experiment demonstrates that the coefficient is greater in practice than what is often theoretically assumed. This is partly due to the fact that the contact-effort between the pulley and the rope is one of " striction," not " friction." Friction, properly, is the resistance exerted by surfaces of bodies in relative motion, and is the result of dynamic forces; whilst striction is the resistance exerted by the surfaces of stationary or relatively stationary bodies, and is a static force, as when a pulley travels at the same rate as the rope or belt. In discussing the question of winding, it is necessary not to confuse static with dynamical forces. Where slip occurs between the pulley and the rope, there is real friction and differential travel of the surfaces in contact. In practice, slip occurs between the usual head-frame pulleys and the friction-made flats or shiny places on the rope. The chances are that there is less " slip " with Kœpe than with other pulleys, but this slip, if noticeable and incorrectible, is likely to be more significant with the Kœpe than with other systems.

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., page 170.

Another factor accounting for good contact-effort is due to the holding efforts on the Kœpe guide and winding-pulleys being reversed at different sections of the rope, and to the length of the surfaces pressed being within a certain ratio to the surfaces and pressure, thus producing a grip which, according to the author's experiments, is 2·56 times the pressure used. The reversal of the stresses of the rope against the pulleys produces this mechanic advantage. This gripping-ratio can be increased up to certain limits, if desired, by truncating the tread of the pulleys or by adjusting the guide-pulley; so that slip is probably not so great a bogie as is often thought.

Rope-capping.—Mr. Raw appears to have tempted the authorities by just nipping off the metalled end of the rope. In some districts recapping means cutting off only that part of the rope enclosed in the capel; whilst in other districts the part of the rope above the capel likely to be affected by load reaction is removed. The author has stated that a winding-rope becomes most fatigued in the immediate region of the socket, due partly to tortional stresses, but doubtless principally to the wave motion in the rope having to terminate there, with the resulting tendency, very much as in the case of sea-waves breaking on the shore, to break the rope at the socket. If this be the case, in cutting off the bottom 8 inches of the rope the part of the rope most deteriorated is left in the capel, and the purpose of recapping—to remove the fatigued part—does not seem to be fulfilled. There is little analogy between sea-wave motion and rope-wave motion. In the case of white-metal and some plug capels, wire-force vibration —not the wave motion of the rope, which is an effect of the wire forces—stops near the socket neck, because it is the dead centre where the full reaction effort is exerted. Both action and reaction take place there, because the solid metal forms no part of the rope. The constant crossing and re-crossing of the wire forces at these dead centres tends to fatigue the wire metal, and destroy the cohesion of its particles, besides producing elongation to the point of fatigue. Hence the " snap " at the neck of white metal and sometimes other plug capels.

The author's comparison of the drum and Kœpe winding is difficult to understand. Efficiency has a cost and safety value, which is evident from the table given. Inconvenience has a cost value only, which time and experience will probably reduce.

Mr. H. W. G. Halbaum (Cardiff) wrote: The owners of Plenmeller Colliery are to be complimented on their enterprise in adopting the Kœpe system of winding in face of declarations recently made by " authorities " that the system is unworkable and impossible. According to Prof. Louis, one of these " authorities " has gone down before Mr. Raw's facts, but I do not think that this is the case. The coefficients of friction are those applying to flat contacts, and it appears obvious that they cannot possibly apply to Mr. Raw's deeply-grooved wheels, by reason of side friction; but, as Mr. Raw has demonstrated, are much higher. It is impossible to entertain seriously the suggestion that oiling the wheel increases its friction, and I can hardly imagine that either Mr. Raw or Prof. Louis is really of that opinion. The natural explanation of the fact lies in the grooving of the elm segments.

The owners of Plenmeller Colliery have shown wisdom in copying Continental practice where it appears to have any advantage over stereotyped British methods, but I think that in some respects they might have gone even further. Why, for instance, have they elected to use continuous current and the Ward-Leonard system? On a recent visit to Blackhall Colliery, I witnessed some tests of the electric winders, and found that at the South Pit the cage could be run in the shaft at the low speed of 5 feet in 9 seconds, when required, which seems to be as perfect control as could be wished for. The current is alternating (2,900 volts), and there is neither Ward-Leonard nor Ilgner apparatus on the place. It is rather difficult to understand why anyone should choose—assuming that he is free to choose—continuous current with Ward-Leonard control, rather than alternating current with simple liquid controllers, such as are in use at Blackhall, and also at the collieries of the Powell Duffryn Company in South Wales (where the loads are moderate, but still greater than those raised at Plenmeller). Of course, where the loads are much greater, it might be better to put in, say, an Ilgner set, as was recently done at the Britannia Pit of the Powell Duffryn Company, where the work required is to wind 360 tons per hour from each shaft from a depth of 2,190 feet.

The arrangement of adjusting screws and links in the two rope-lines, one set of links with its screw being twice as heavy as the set of links on the other side, does not appear to be quite ideal, although "borrowed from Continental practice." Is the Kœpe system really inseparable from such foreign devices? I do not think so, but think it rather humiliating to borrow foreign ideas in their entirety without intermingling therewith one solitary original idea of one's own. I am very anxious that the Plenmeller scheme should be succesful, and shall be very disappointed if it does not prove so. I hope that Mr. Raw will be able shortly to put something of his own into the mixture that he has borrowed, remove these clumsy links, put something more worthy of an engineer's brain in their place, and so give the scheme a chance of success, and impart to it a symmetry which it lacks at present.

Mr. H. F. BULMAN (Acklington) wrote: With regard to the consumption of steam in winding-engines, it might interest the members to compare the figures given by Mr. Raw with some figures previously published in the *Transactions*. Mr. Raw states that "with the plant working at about half capacity, the actual steam-consumption is about 23 pounds per shaft-horsepower, the colliery generating sets consuming 17 to 18 pounds of steam per Board-of-Trade unit." It may be noted in passing that turbo-generators are now constructed to give at full load a guaranteed steam-consumption of 10·2 pounds per Board-of-Trade unit.

From figures supplied by Mr. W. C. Mountain,* the estimated steam-consumption of winding-engines at thirteen collieries in various parts of Great Britain ranges from a minimum of 43 to a maximum of 178 pounds per shaft-horsepower, the average being 111 pounds. Dr. Karl Schultze† gives the steam-consumption of three winding-engines, as determined by measurement, at from 34·9 to 134·8 pounds per horsepower-hour. The engine in the former case is a compound engine working condensing, and in the latter a twin engine working exhausting into the atmosphere. He states that "the average consumption of net winding steam for all three shafts was found to be 87·5 pounds per shaft-horsepower-hour of saturated steam." These figures show by comparison the economy of the electrically-driven overhead winding plant described by Mr. Raw.

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* "The Utilization of Exhaust-steam for Collieries, Ironworks, etc., and the Cost of Electric Current Generated," *Trans. Inst. M. E.*, 1913-1914, vol. xlvii., page 409.

† "Colliery Consumption and Machine Economy at an Upper Silesian Colliery," *ibid.*, page 576.

Now that the plant at so many collieries is driven entirely by electricity, it would be useful if some normal standard of the mechanical power required per ton of coal produced and the cost could be ascertained.

Mr. George Hann has given the consumption of power during one week in January, 1917, as 282,600 units for an output of 10,158 tons of coal, or about 28 units per ton.* During a week in November, 1917, it was 406,300 units for an output of 12,529 tons, or about 32 units per ton. This gives an average of about 30 units per ton of coal.

With regard to cost, in a recent discussion before the Mining Institute of Scotland† the cost of mechanical power in ordinary colliery work is stated to be ½d. per horsepower-hour, or £18 per year. According to Mr. C. E. Stromeyer, of the Manchester Steam Users' Association, in a modern factory, with fuel at 12s. 6d. per ton, when working about a third of full time, the cost of an indicated horsepower is £12 a year. Where waterfalls can be utilized, as in Norway and Sweden, the cost of continuous power production is said to be as low as 35s. to 50s. per electric horsepower per year. The cost of a horsepower-year generated by a 2,000-horsepower recovery producer-gas plant has been estimated by Mr. T. Roland Wollaston to be £2 17s. 11d. at pre-war prices, allowing credit for the sulphate and tar produced. Assuming that 3,000 horsepower is a normal requirement of mechanical power of a large colliery, the cost of £18 will be £54,000 a year. Evidently there is considerable margin for economy, and its importance is increasing as manual labour becomes more costly. Perhaps Mr. Raw can supply some information as to the mechanical power required at Plenmeller Colliery, and the cost of it.

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* "Paper on a Modern Colliery," *Proceedings of the South Wales Institute of Engineers*, 1918, vol. xxxiv., page 215.

† *Trans. Inst. M. E.*, 1917-1918, vol. lv., page 137.

RECORD OF GAS-PRESSURE FROM A BOREHOLE.

By CHARLES J. FAIRBROTHER.

I submit the enclosed photographs (Figs. 1 and 2) as being of general interest, for, while there are many records of high pressures of gas issuing from seams of coal, actual photographic representation is rare.

The Durban Navigation Collieries, Limited, decided to prove the continuation of their coal to the west of their present property at Dannhauser. A borehole proved a sheet of diorite, 330 feet in thickness, overlying the seams, and the coal was reached at a depth of 773 feet from the surface.

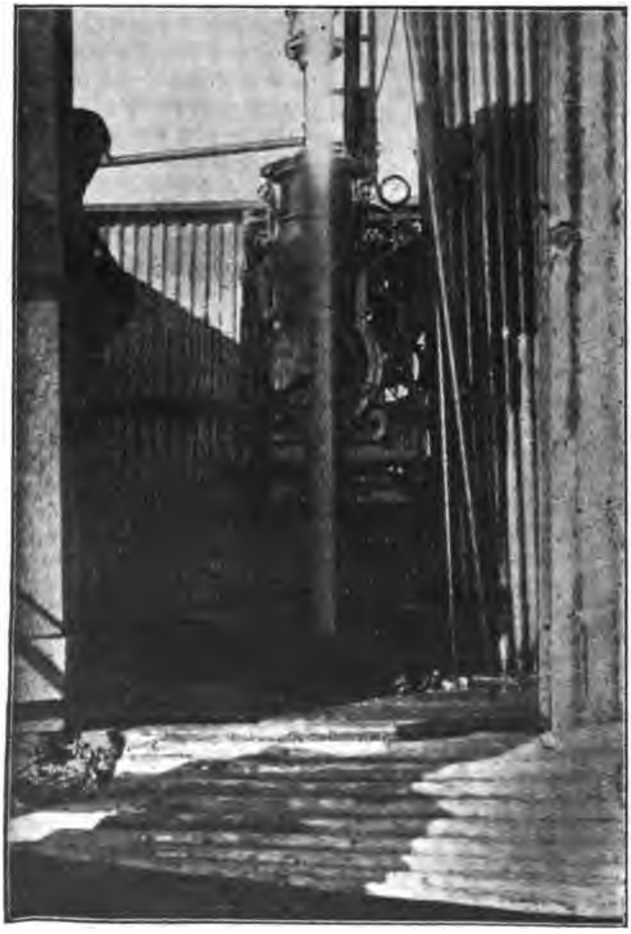

Fig. 1.—Gas Blowing out of the Borehole while clear of the Rods.

Two seams of coal occur, the upper being about 3½ feet thick and the lower about 5¼ feet, with one small band of stone near the bottom. The two seams are separated by about 2 feet of parting.

The boring had not reached many inches into the upper seam when gas began to appear, and before a foot had been penetrated it was blowing off at high pressure. The noise was like the blowing-off of a battery of high-pressure boilers, and made it quite impossible for the human voice to be heard above the din, so that the borers had to work by signs.

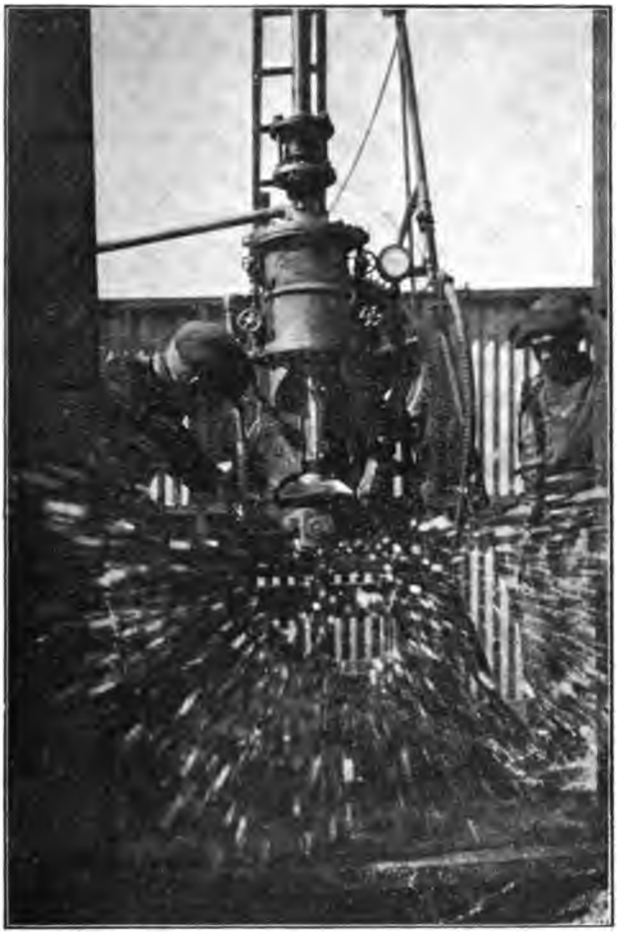

Fig. 2.—Borehole with Rods in and Water being Blown in all Directions by the Force of the Gas.

The photographs were taken while the lower seam was being cut. Fig. 1 shows the gas blowing out of the hole while clear of rods, whilst Fig. 2 shows the hole with the rods in and the water blown by the gas in all directions.

An attempt was made to register the pressure with a pressure-gauge screwed into the top of the casing, and a pressure of 150 pounds to the square inch was reached in a few seconds; but, as the casing began to lift, the pressure had to be released, and nothing further was done in that direction.

The Chairman (Mr. Frank Coulson): The pressure referred to is considerably less than has been got in coal-seams in the County of Durham.

Mr. J. B. Atkinson (Newcastle-upon-Tyne): Sir Lindsay Wood has recorded a maximum pressure of 461 pounds to the square inch in his experiments.* Mr. Fairbrother speaks of "gas issuing from seams of coal," but I do not think that gas in fiery strata comes only from the seams of coal, but from the adjoining strata as well as from the coal, in proportion to its capacity to hold gas. It might be that certain strata, such as sandstone or post, can actually hold more gas than coal itself, and I have seen several cases in which this seems to be probable. Buddle in his account of Wallsend Colliery† said, many years ago, that most of the gas with which they were troubled in the High Main was contained in the post roof. If gas exists at high pressures, it is not conceivable that it should remain confined to the coal-seams. It will dissemminate itself, in the course of millions of years, over all the adjoining strata. It cannot be the gas itself that is seen in Fig. 1, but probably water that was blown out by the gas.

The Chairman: Is it not possible to see the gas? Has not the gas frequently come out almost like smoke from a bore-hole? I remember a case where in sinking a depth of about 120 feet, where there were no coal-seams, a large quantity of gas was encountered, and in putting in some plank-tubbing a 10-inch, a 4-inch, and a 3-inch pipe were all blowing off at high pressure. Frequently the black colour of the gas is quite visible, and resembles a chimney smoking with a fairly dense smoke.

Col. W. C. Blackett (Sacriston): I do not think that it is gas that is seen. When gas at high pressure is liberated, the reduction in temperature is considerable, and any moisture present condenses and forms a cloud, and it is this that is seen. In a hot place in a mine after an explosion, when the cold air is brought in it often appears as though one actually saw the gas.

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* *Trans. N.E. Inst.* 1880-1881, vol. xxx., page 222.

† "Mining Records," by John Buddle, *Trans. Nat. Hist. Soc. Northumberland, Durham, and Newcastle-upon-Tyne*, 1838, vol. ii., page 326.

Mr. J. B. **Atkinson**: I have noticed the same phenomenon, and believe that it is the origin of the term "whitedamp."

Mr. M. W. **Parrington** (Wearmouth): It is difficult to realize that a borehole going into a seam of coal can give off gas rapidly enough to cause a noise like a battery of steam boilers. Of course, if the borehole in question penetrated into a cavity full of gas, this would account for the noise.

Mr. **Atkinson**: Probably a fissure connected with considerable sources of gas was struck in the coal.

Mr. C. C. **Leach** (Seghill): The great difficulty at Harton Colliery was to get the holes made gas-tight.

The **Chairman**: Can Mr. Atkinson state whether the gas is generated in the coal-seams and fills into the post and other strata?

Mr. **Atkinson**: This is not quite certain, but it is most probable. Natural gas is sometimes got where there is no coal-seam, but, still, on the whole, the firedamp is probably from the coal-seam, although in a long period of time it must have disseminated itself through the whole of the strata. In descending a wet sinking pit that passes through fiery strata, one can hear the sides hissing all the way down. I think it quite a fallacy to suppose that firedamp is confined to coal-seams, but this is a fallacy that seems to be very generally held.

Mr. **Parrington**: There is no doubt that gas is contained in the soft shales as well as in the coal-seams. Many years ago it was desirable to produce as large coal as possible, and I conceived the idea of " winding " the coal, that is, draining the gas out of it by driving in the soft cover on the top. When a place was entered in the soft shale on the top of the coal, it was found to be just as soft as the coal itself, and behaved in exactly the same way. The gas threw off great " shives " of the shale, just as it had thrown off great " shives " of the coal.

Mr. **Atkinson**: I suggest that this might have been due to the pressure of the strata above.

A **Member**: Is it not a fact that oil and gas come off from a strata not necessarily associated with seams of coal? I remember when travelling through Pittsburgh some years ago that they had to go through the Coal-Measures to get into the gassy strata.

The **Chairman**: In cases where there is water-bearing strata, and the bottom of that strata is reached, is not the gas met with

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The **Chairman**: In cases where there is water-bearing strata, and the bottom of that strata is reached, is not the gas met with immediately at the same pressure as the static pressure of the water?

Mr. ATKINSON: The late Mr. A. L. Steavenson suggested that the pressure of gas would be equal to that of a column of water equal to the depth from the surface of point of observation. I do not know whether that statement is true, but I think that it is likely.

The CHAIRMAN: In the Durham Coalfield one frequently meets with blowers of gas from the clay, above the Coal-Measures altogether, in strata through which one would think that the gas could not pass. At Hutton Henry Colliery, for instance, some pipes were put in through the walling when the pit was opened out a second time to release the gas, which could be ignited as it issued from these pipes. I suppose that this would be marsh-gas.

Mr. ATKINSON: It was probably firedamp from the Coal-Measures below. There are or have been places in the County of Durham in which, in similar circumstances, the gas could be lit at any time.

THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

ANNUAL GENERAL MEETING,

HELD AT UNIVERSITY COLLEGE, NOTTINGHAM, SEPTEMBER 12TH, 1918.

MR. GEORGE SPENCER, RETIRING-PRESIDENT, IN THE CHAIR.

Mr. H. Eustace Mitton was unanimously elected president for the ensuing year.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

Held in the Wood Memorial Hall, Newcastle-upon-Tyne,
October 12th, 1918.

Mr. JOHN SIMPSON, President, in the Chair.

DISCUSSION OF MR. GEORGE RAW'S "NOTES ON THE OVERHEAD KŒPE WINDING PLANT AT PLENMELLER COLLIERY, HALTWHISTLE, NORTHUMBERLAND."*

Mr. **George Raw**: Mr. Hanley and Mr. Halbaum are evidently both dissatisfied with the rope-adjustment screws and links. Mr. Hanley suggests the introduction of "the principle of the extension-carriage" and Mr. Halbaum "something more worthy of an engineer's brain" than the "clumsy links." Incidentally, the Plenmeller plant was designed and constructed, although not erected, prior to my association with the colliery. The principle of the sliding carriage was carefully reviewed, but it was found that the new stresses introduced would involve reconstruction of the whole tower, so that although admittedly clumsy the adjustment-screws and links was the best compromise for a completed if unerected plant. The arrangement chosen was preferable to the hinged platforms that were frequently used on the Continent to overcome the difficulty, which, when the winding-rope is too long and the cage in consequence too low, cause the tubs to jump into the cage much too vigourously. The idea of the extension-carriage is an old one; but, if I had to consider an entirely new Kœpe winding plant, I am disposed to believe that it would be found to be the most satisfactory solution of the problem. Several possible arrangements of an adjustable pulley have been suggested from time to time, but some of them, in my opinion, largely defeat the object of the Kœpe system by increasing the mass of the moving parts to very nearly that of the ordinary winding-drum.

I disagree with Mr. Halbaum with regard to the side friction of the pulley-groove on the rope. The segments, although made of hard wood, by wear quickly lose all their wedging tendency on the rope; and in any case the fundamental laws of friction eliminate any consideration of the extent of the surfaces in contact. The corroborative test detailed in the paper supports this view when a Lang's lay-rope $\frac{11}{16}$ inch in diameter on the actual trod of the guide-pulley gave a value of 0·35 for μ against 0·30 for the 1⅝-inch diameter flattened-strand winding-rope.

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., page 170; and 1918-1919, vol. lvi., page 1.

Mr. Hanley's distinction between "friction" and "striction" has admittedly a number of well-established relative values; but, so far as the wood-lagged Kœpe pulley is concerned, the distinction is, I consider, rather a fine one for practical purposes.

There is undoubtedly a great deal to be urged in favour of Mr. Halbaum's remarks with regard to the Ward-Leonard control, although the Ilgner system has an undoubted advantage in rounding off the load-peaks where such peaks are of consequence.

Mr. Bulman's review of steam and electrical consumption figures is of much value, but his request for particulars of the colliery's mechanical power and its cost would unduly extend the scope of the paper.

DISCUSSION OF MR. CHARLES J. FAIRBROTHER'S "RECORD OF GAS PRESSURE FROM A BOREHOLE."*

Lieut.-Col. **HARRY RHODES** (Rotherham) wrote: I am well acquainted with the Durban Navigation Collieries, and on making an inspection of the mine in question early in 1914, I was very much struck by the amount of gas given off in the winning-places in the direction where the borehole referred to by Mr. Fairbrother has since been put down. At the time of my visit these winnings had just got through one of the whin dykes that are so common in the Natal Coalfield, and although there were only seventeen places, each 18 feet wide, opened up in the district in question, the Clowes lamp showed 1¾ per cent. of gas in an air-current of 28,700 cubic feet per minute. It would be interesting to know whether this gas still continues to come off.

Sheets of diorite, otherwise described as "whin floats," such as are referred to by Mr. Fairbrother, are not at all uncommon in the Natal Coalfield, and the whin dykes are evidently the channels by which these sheets or floats were injected from below. An area, therefore, covered by a "float" and cut off on all sides by whin dykes forms, as it were, an entirely isolated pocket; and as this rock is practically impervious to both water and gas, it is highly probable that a greater pressure of gas would be registered from seams lying at comparatively shallow depths in Natal than would be the case in England.

In other cases with which I am acquainted in Natal, gas came off very freely just after a whin dyke was pierced, especially when the area was overlain by a float, but after some months the gas appeared to gradually drain off.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 6.

SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

ANNUAL GENERAL MEETING,

HELD AT THE UNIVERSITY, EDMUND STREET, BIRMINGHAM, OCTOBER 14TH, 1918.

MR. LANGFORD RIDSDALE, RETIRING-PRESIDENT, IN THE CHAIR.

Mr. **WILLIAM CHARLTON** was unanimously elected President for the ensuing year, and delivered the following Address:—

PRESIDENTIAL ADDRESS.

BY WILLIAM CHARLTON.

I have to thank the members of this Institute for the honour they have conferred upon me by my election to the Presidential chair. I trust that my occupancy of it will not do anything to detract from the high traditions my predecessors have established.

During the last four years the activities of our Institute have been somewhat curtailed. Members have had to devote the whole of their energies to the business of keeping the collieries in their charge up to their utmost producing capacity. The drafting of so many workers into the army, with a consequent derangement of routine operations, and the difficulties in procuring timber and all the essential stores and materials required, have imposed an enormous strain on managers of collieries. Their anxieties have ever and anon been added to by labour unrest and sporadic strikes. A great number of our members have also shared the anxiety and griefs which have spared but few homes in this country.

Taking into consideration all these circumstances, it is gratifying that the Institution has preserved a healthy life and is immediately capable, as soon as normal times prevail, of resuming all its old-time activities.

I propose in my following remarks to make a small contribution to the subject which is uppermost in most minds and of extreme national importance at the moment, namely, the question of output. The subject will be considered under two heads: first, the immediate and pressing need for the United

Kingdom to produce the utmost possible quantity of coal; and, secondly, the standpoint of output per unit of person employed, and its bearing on the prosperity of the coal industry, and those other industries whose ultimate economic position is affected by the use and cost of fuel.

The causes which have made the question of output of coal an extremely urgent matter at the moment scarcely need recapitulation. There has been since the commencement of the war a marked decline in the produce of British mines. This decline may be due in a minor degree to several causes, but is primarily due to the recruitment of miners for the army. At the outbreak of war some 250,000 miners answered Lord Kitchener's appeal—roughly a quarter of the whole of the persons employed at mines and a still larger proportion of those engaged underground.

It is not enough to simply count heads when considering the effect that the withdrawal of these men had on the mining industry. They were the fittest and most capable men, a very large proportion of whom were engaged in those services in a mine that require youth and agility, services that cannot be performed by boys under a certain age and which older men find difficult and irksome. In any attempt, therefore, to arrive at the causes of decline in the output this point must be kept in mind.

The recruiting of miners has continued until something like 400,000 are now in the army. To a considerable extent they have been replaced by other labour, but this lacks the training and genius of the life-long miner, and is not comparable in efficiency with the labour of those men who have become soldiers.

There are other causes directly due to war conditions which have contributed to a reduction of gross output. These are indicated in brief quotations from the Divisional Mines Inspectors' Reports for 1917. Mr. Henry Walker (Scotland Division) writes: " In certain parts of the division employment has been good; in those parts from which the output of the mines in normal times was shipped abroad it has been bad, but towards the end of the year was improving." Mr. J. Dyer Lewis (South Wales) gives, as reasons for a reduction of 3,500,000 tons in output, " insufficient supply of tonnage, disputes, and absenteeism." Mr. J. J. R. Wilson (Northern Division), in explaining a decrease of over 4,000,000 tons, says it is due " to the short time worked as a consequence of the lack of shipping, and also to the fact that at several mines so many hewers instead of mining coal had to leave the face to do stonework."

It is interesting to note that in divisions not largely or at all dependent for the continuous working of their mines on shipping facilities there were in 1917 slight increases in output on the previous year. The York and North Midland Division reported an approximate increase of a million tons; the Lancashire, North Wales, and Ireland Division reported an increase of 300,000 tons; whilst the Midland and Southern Division recorded an increased coal output of nearly 163,000 tons.

The alarm which has arisen in the country on the question of the adequacy of our coal supplies is due to the figures for the first two quarters of the current year. In the first there was a decrease of a little over 4,000,000 tons, and in the second an estimated reduction of nearly 5,500,000 tons on the preceding year. As the full effect of the last comb-out of miners for the army was not felt in the first quarter, and perhaps was not fully operative in the second, it is easily seen that the produce for 1918 will be considerably less than that for 1917. So far, this enquiry has revealed two main causes for decline in output—recruitment of the most efficient and able-bodied miners and shortage of shipping, resulting in short time being worked.

There are two other causes, which a truthful survey of the subject compels the speaker to notice. These are sporadic strikes and absenteeism. Reference to these is not agreeable, and I would abstain, if possible, from referring to them, believing that at the moment recriminations, charges, and counter-charges between the community and those engaged in getting coal, or between sections of the latter, will not conduce to harmony and the accomplishment of what is at the moment a vital necessity—the greatest possible output of coal. This object can be most surely attained by mutual goodwill and combined effort.

With regard to the casual and sudden abstentions from work which have become a regrettable feature of industrial life, it is difficult to speak. On the one hand, it is not desirable to put forth irritating charges; on the other hand, these occurrences cannot be passed over without comment, as they do to an appreciable extent affect output. It would appear that the accepted method of protest against grievances real, imaginary, and frivolous is to stop work. Under present conditions of strained nerves it is advisable that complaints and alleged grievances should have immediate investigation, and not be allowed to drift, with the usual concessions after strikes. A policy of more candour both ways would mitigate the painful occurrences and improve relationships. At the same time, those responsible for these all too frequent "play days" should realize their part and responsibility to the community. It is not the duty of owners and managers alone to keep the pits going and produce the maximum amount of coal; labour is as dependent as any other class on this being done, and has on its shoulders an equal obligation. The gospel of getting as much as possible out of the industry without sharing the responsibility for its conduct and prosperity is morally wrong and politically inexpedient.

I cannot find, for the consequences of these disputes and stoppages of work, better or more apposite remarks than those contained in a quarterly report of the General Federation of Trade Unions:—

> "Such strikes confuse the army, comfort the enemy, alienate public opinion, and build up a general hostility which will react seriously when the war ends and ordinary economic conditions again operate. . . . . . Some day the war will end. Some day ordinary economic laws will operate again, and the union with discredited officials and damaged credit will have a very unhappy time. The older and experienced trade unionists know this, but many thousands of them are in France, and for the time are voiceless and voteless, while hundreds of thousands of new-comers, many of them trade unionists by compulsion for the first time, are like amateurs with a powerful weapon. Many of these are not trade unionists in spirit, and will quit the movement the moment circumstances change; in the meantime they are creating dangerous precedents and hostilities. Their careless disregard of commonsense and economic law is reducing national credit, inflating the currency, and increasing the price of every commodity the workers themselves use."

The establishment of pit committees, on which all parties are to be represented, for the investigation of all kinds of grievances, thus affording opportunities for frank intercourse, should do much towards eliminating this source of trouble.

Absenteeism has many phases. Figures clearly show that it is most prevalent amongst "face" workers and those with the maximum earning capacity. The subject has been repeatedly dealt with by the Coal Mining Organisation Committee, composed of representatives of both employers and employees. In their first report they state that the pre-war percentage of absenteeism in the whole of the United Kingdom was 10·7. For the war period over which figures were taken the percentage was reduced to 9·8.

It is to be regretted that these and subsequent figures do not show the proportion of *avoidable* absenteeism, for with nearly a million workers engaged there must be a fairly constant and appreciable proportion who for many and various reasons are unable to attend to work, and there is some justification on the part of workers for irritation in that these figures are often quoted without this necessary modification.

Average figures of the whole of the employees do not give a correct statement of the case, for in their second report the Committee give the following analysis, showing the proportions of the different classes of workers:—For one quarter, March to September, 1914, miners paid by contract, 16·65 per cent.; March to September, 1915, 15·6 per cent.; two fortnights in September, 1915, 18·4 per cent. In the same periods the percentages of absenteeism amongst other grades of underground and surface workers ranged from 5·1 to 6·5.

A return issued by the South Wales and Monmouthshire Coal Owners' Association of absenteeism at some 275 collieries in that coalfield showed over a period of three months an average of 11·74 per cent. The return showed that the highest percentages prevailed on Mondays and Saturdays.

Most coalfields show that the percentage of absenteeism is greatest on a Monday, sometimes climbing to the appalling figure of 30 per cent. This condition of the greatest abstention from work occurring on the day after the Sunday's rest completely demolishes the argument, sometimes put forward, that abstention from work by a large proportion of the men is due to the physical impossibility of their doing a full week's work.

Whilst on this matter I should like, however, to record the following incident related to me by one of H.M. Inspectors of Mines:—When examining a range of work in a certain pit he entered into conversation with a rather elderly stallman, who informed the Inspector that he took one day off per week, and that his mate, of similar age, did the same. Owing to their age, they stated that they were not able to do a full week's work, but he added that the two of them never stayed away on the same day, so as not to put their stall to " play." I have not the slightest doubt that there are many thousands of men equally thoughtful and possessed of the same sense of personal responsibility. All observation and experience lead to the conclusion that abstention from work, resulting not only in a limitation of output but serious inconvenience, loss, and disorganization in the working of collieries, is indulged in by men of comparatively limited age and good physical condition. It presents a striking contrast, at the moment, to the conduct of the thousands of " munition girls " who go from mining villages every day to the munition works, often many miles from their homes, and work for fourteen hours or more a day, and it is a mere platitude to say that coal is just now our primary munition of war. Drastic measures to prevent deliberate abstention from work are suggested in some quarters, and with the logic of those proposals no one can quarrel, seeing that the whole forces of the country and empire are being mobilized to gain such a military victory as will ensure a satisfactory peace; but personally I should like such a moral sense of responsibility to prevail amongst workers in our mines that they will achieve what is desired, and that persistent slackers would become Ishmaels in their midst. If by this means an increase, even small in output, can be obtained, no legacy of bitterness will remain to the future to mar the co-operation and harmony that will be essential if, after the war, we are to reconstruct our industrial conditions on a better basis than has hitherto prevailed.

Absenteeism is stated to be due in some cases to unwillingness to earn so much money as to come within income-taxable limits. At first this seemed incredible, but investigation shows it to have a basic existence in fact. In men who have at one time been earners of less than the amount at which a man or woman becomes liable to income-tax, but by work and study have long passed that limit, this conduct is utterly incomprehensible. It is a strange commentary on our 40 or 50 years of compulsory elementary education that there are existing now people who are pound foolish and two and threepenny wise.

It is gratifying to record that the appeals of Sir Albert Stanley and Sir Guy Calthrop are being seriously and critically examined by all classes of miners. The heckling and criticism to which they are being subjected can, with our men, only result in the dissipating of suspicion and misunderstanding, and in contributing to the desired result of a strenuous prosecution of the war and in minimizing the threatened inconvenience and hardship of the civilian population by the provision of more coal.

Before leaving this phase of my subject I would strongly suggest to the miners' organizations that they should on their own initiative ask that the clause of the Eight Hours' Act which can suspend its operation during a time of national emergency should be put into operation forthwith. Whatever safeguards and conditions they cared to attach that would on the suspension of hostilities and the passing away of the coal crisis restore the *status ante quo* would almost of a certainty meet with acceptance. It would add one more to the obligations which the community is already under to its miners and immeasurably strengthen their claims for future regard on public opinion. It would be a fitting climax, in this period of victory, to the magnificent response that our lads made to the country's call in the dark days of 1914.

The second phase of the subject, namely, the question of output per person employed, is one that calls for most serious thought and attention. The Coal Conservation Committee draw attention to the fact that in the decade 1904 to 1913 the annual output per person employed underground in British mines declined from 347 to 321 tons. When estimated on the total persons employed above and below ground, the figures declined from 279 to 259 tons per annum. In the first case the decline on underground workers alone is 7·5 per cent. On the surface and underground workers together the decline is 7·2 per cent. In the first three years of the decade the figures were 347, 348, and 360 tons per person employed underground. Since the year 1906, when the figure of 360 tons was reached, there has been a fairly regular decline, the regularity being disturbed in those years when there were strikes, of such magnitude and duration, as to appreciably affect the gross output of coal from the country as a whole. How the output per man has been influenced by these and legislative changes is shown in Table I.:—

TABLE I.—SHOWING HOW THE OUTPUT OF COAL PER MAN HAS BEEN INFLUENCED.

Year.	Tons produced per person underground.	Strikes, conditions of trade, legislation.
1906	360	—
1907	359	—
1908	334	A year of bad trade generally. Lancashire cotton strike, which caused many pits to work short time.
1909	327	Eight Hours' Act came into operation in all districts except Durham and Northumberland.
1910	317	Eight Hours' Act came into operation in the two northern counties. Cessation of work in many collieries in these counties till the end of April. South Wales strike, over 12 months in Aberdare Valley from September, 1910, and in numerous other collieries for nearly three months. Warwickshire strike from 11 to 15 weeks.
1911	320	—
1912	301	National strike, affecting nearly all mines during March and early part of April.
1913	321	Lancashire strike, lasting six weeks.

It has to be stated that coal-mining in this country is progressively more difficult. Deeper mines, longer underground journeys, and the working of thin and difficult seams that hitherto were not regarded as good commercial propositions, all contribute to reduce the output per person and increase cost.

The science of mining engineering has in all probability kept pace in its increasing efficiency with these difficulties, and it is worth noting that in 1913, the year immediately preceding the outbreak of war, there was an increase of underground workers in mines of 3·7 per cent. over the previous year and an increase of gross output of 10 per cent. The calamity of 1914 makes comparisons with that and subsequent years valueless. The impression on the writer's mind is that immediately prior to that year great improvements and advances in mining practice were being effected. It would perhaps be difficult to prove, but

I am also firmly of the opinion that but for that increased efficiency and enterprise the country would long ere now have reached a more serious coal crisis than that of the immediate future; in short, that the difficulties of carrying on collieries and maintaining the output have been largely overcome because of the progressive professional efficiency and enterprise already in operation prior to the outbreak of war.

The Coal Conservation Committee, however, draw particular attention to the decline in output per person; they state that it is a matter of grave concern as affecting the ultimate cost to the community, and make comparisons between ourselves and the other two chief coal-producing countries of the world. Their comparisons summarized are as follows:—

TABLE II.—COMPARISON OF OUTPUT OF COAL BETWEEN THE UNITED KINGDOM, UNITED STATES OF AMERICA, AND GERMANY.

Output of coal per person employed (persons above and underground).

Year.	United Kingdom	United States of America.	Germany.
1905	282	560	242
1906	292	577	264
1907	292	630	258
1908	271	538	243
1909	266	617	236
1910	257	618	239
1911	260	613	248
1912	244	660	269*
1913	259	681	273*
1914	—	601	—

* Estimated.

The broad fact outstanding from this comparison is that whilst our own output per person has declined, that of other countries has increased, that of the United States considerably, and that of Germany but very little, if the two last returns, about which there is some doubt, are eliminated.

The high figures for the United States call for comment. It is a comparatively younger coal-producing country than ours. It has immense natural wealth in coal, and it is now in a stage of development that this country passed many years ago. Its richest and easiest worked seams are still producing, whilst ours are almost exhausted. But the outstanding feature of United States mining is the enormous extent to which they make use of power in getting coal.

The problem that confronts the mining industry of this country, and particularly the professional miner, is not only how to arrest the downward tendency of produce per person, but if possible to reverse that tendency. The economic aspects of this question were admirably stated recently by the President of The Institution of Mining Engineers: (1) The price that can be obtained for coal in this country must be limited if the industries depending on it are to keep their costs of production within economic limits; (2) coal for export will have to meet with an increasing amount of competition. I am not unmindful in stating case No. 1 that an enormous increase in productive power has been shown to be possible by improved methods of generating, distributing, and utilizing power in home industries, and, either effecting a great saving in the home consumption of fuel, or, alternatively, by the economical use of fuel, generating an increased amount of cheap power, thereby greatly increasing the producing capacity of home industries. Whichever view may be taken, the coal-trade cannot expect to reap the whole advantage, and the limit of economic price must sooner or later be reached.

The problem of the increased production of coal per employee has been definitely presented to the mining community by the Coal Conservation Committee. But the problem has always been with us, although perhaps not realized in all its bearings as now. One of the chief reasons for the existence of this Institute is to so promote technical efficiency as to accomplish this and other desirable ends. The Committee suggest that the object may be promoted by " the application of a systematic and well-defined mining policy," the adoption on a larger scale than hitherto of mechanical contrivances for coal-getting and transport; and in connexion with the latter the adoption of a predetermined plan that permits of routine and elastic development. The *Transactions* of this Institution and of the South Wales Institute of Engineers furnish some striking examples of the concrete realization of most of these apparently abstract principles. The recently-contributed paper by Mr. George Gibb* is worth some attention. Mr. Gibb has boldly challenged the shibboleths of the longwall system of working, and claims that his modifications have to a large extent got rid of many of its drawbacks, such as pressure, cost of road repairs, lack of concentration, and the application of mechanical haulage close up to the face. Mr. Gibb's paper is all too brief for the claims he makes for his accomplishments, but it is thought-impelling and suggestive.

Another contribution to mining literature bearing on the problem under discussion is that of the late Mr. George Hann, describing the method of opening-out and developing the Britannia Colliery of the Powell-Duffryn Company in South Wales. Concentration and mechanical transport, combined with scientific laying-out and design, have accomplished results which are worth quoting. In a 4 to 4½-foot seam—

> " the yield per yard of face per day for the colliery averages 16 to 17 cwts., or from 12,000 to 13,000 tons are got per week from 2,400 yards of working

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* " Fresh Aspect of Intensive Mining Thin Seams," *Trans. Inst. M. E.*, 1917-1918, vol. liv., page 28.

face. The yield per yard of face would be greater if more men were available.

"Mechanical haulage from the face in stall-work has failed because of the difficulty of running a rope into each road for one tram—the output per engine is too low with this method; but, with the conveyor, an output of 250 tons per day can be brought to one loading place, and this quantity of coal justifies the use of a hauling-engine. To show what the average yield per loading-place is, an output of 12,500 tons for the week was obtained from fourteen loading-places—two of these were developing faces and so lowered the general average. The maximum output from one loading-station in a week is rather over 1,600 tons, the length of the face being 200 yards."*

These two cases are here briefly referred in order to show that leading minds have already tackled the great problem, and their example will be a guide and stimulus to the rest of professional miners in dealing with their own particular cases and circumstances.

May I now summarize the points I have tried to place before you?

(1) There has been a decline in output of fuel during the war period. This has been accentuated during the early part of this year. This reduction in output is due primarily to military needs for fit men, who have gone from the mines, and the shortage in shipping, also brought about by the conditions of war. This position is made the more serious because of the increased demand for fuel for the navy and for war industries in this country and in those of our allies, and by the requirements of the great American army now aligned with France, Britain, and Italy on the Continent of Europe.

(2) The output from mines is prejudiced by an appreciable amount of voluntary abstention from continuous work by a small section of miners. A reduction in this, or its entire elimination, would both increase output and make the control and management of mines more effective and efficient.

(3) Frequent and mostly unjustifiable strikes affect the gross output of coal, not only as measured by the loss of coal that could be drawn during the time strikes last, but by impairing the producing capacity of the mines for some time afterwards. Immediate consideration of alleged grievances by those in authority and an increased sense of responsibility on the part of employees should eliminate this cause of loss of output.

(4) The reduction of preventable absenteeism and the elimination of unjustifiable strikes whilst doing something to minimize the coal crisis will not be enough. A voluntary suspension of the Eight Hours' Act during the crisis would in all probability remove anxiety by materially increasing the gross output.

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* "Paper on a Modern Colliery," by George Hann, *Procs. South Wales Inst. Engineers*, 1918, vol. xxxiv., pages 230-232.

(5) Both before and during the war period there has been a diminished produce of coal in British mines per person employed. Dismissing from consideration the war period, the position so far as the coal-trade and its dependent industries are effected is still one of grave concern.

(6) The direction in which effort may be most effectual in altering this condition of affairs is that of scientific organization of coal-getting and transport, and a bold investigation of old-time methods, with a view to the adoption of those that would avoid its diffused character, permit of concentration of operations, and the more extended use of mechanical transport at and near the coal-face.

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
Held at the University, St. George's Square, Sheffield,
July 25th, 1918.

Mr. W. D. LLOYD, President, in the Chair.

DISCUSSION OF MR. H. C. JENKINS'S PAPER ON "UNDERGROUND CONVEYORS."*

Mr. H. C. Jenkins (Sheffield) wrote, in reply to the previous discussion (Vol. LV., page 116): In one instance in Scotland the datal men filled 15 tons per man within one week of the installation of the conveyors, and ten men averaged 140 to 150 tons per shift on 100 consecutive days.

In reply to Mr. Drinnan, it would, perhaps, be within the scope of another paper to state cases where conveyors have been a failure, although case No. 3 in Appendix I. records one failure. I am sure that it is agreed that it would be useless to cite as typical the results obtained with conveyors where the conditions are not suitable. Several instances have occurred in which seams have been inspected and reported as unfavourable for the installation of conveyors. I do not agree with Mr. Drinnan that conveyors are installed only in thin seams, as their use is now extending to much thicker seams. The difficulty mentioned in his remarks regarding the roof must, of course, be considered and taken into account when introducing conveyors. The facility or otherwise of dismantling, removing, and re-erecting, or "moving-up" conveyors varies very much, depending greatly on the system adopted by the management, the roof conditions, the thickness and the inclination of the seam, and the type of conveyor. Two to 2½ hours for two men to move any type of conveyor should not be taken as an average time, but belt-conveyors are being moved up regularly in this time.

Mr. Wroe asks for an explanation of several points mentioned in the paper. Mr. Wroe has had such extensive experience in the use of conveyors that I am glad to note that he agrees with some of the statements made in the paper. Further details regarding the Durham colliery equipment, with reference to certain facts questioned by Mr. Wroe, are as follows:—

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., pages 2 and 116.

In the first case, Mr. Wroe makes a mistake in assuming that I referred to a machine-cut face. The figures given are for hand-got coal. The average height of the seam in which an output of 400 tons was maintained in 10 hours with tubs of 8 cwt. capacity was 2 feet 8 inches, and the number of hewers employed at the face was nineteen.

The second point raised by Mr. Wroe referred to the operation of " flitting " or " moving-up." There are six men on the face altogether during this operation; two of them move the conveyor forward within the time stated, and then assist the other four in drawing and setting timber.

Another point which Mr. Wroe omitted to notice was that the belt is cut into 20 to 25-yard lengths, compared with Mr. Wroe's 90-yard lengths. I stated in the paper that by adopting these lengths the " flitting-time " was reduced by 3 hours or more.

It may be of interest to know that, in order to overcome the variations of both roof and coal, it was necessary to alter continually the distance of the chocks from the face, and also vary considerably the amount of small coal placed under the chocks to allow the roof weight to act upon the coal-face so as to " work " it, and that owing to these circumstances alone has it been possible to keep the output at all regular.

Another point which Mr. Wroe has probably not noticed is that at this colliery small stands are used for carrying wooden rollers, whereas Mr. Wroe uses wooden rollers set into props, which take more time to set, so that his statement that such a rapid "change-over" is an impossibility would be quite correct if a 90-yard belt in one piece was being used. I would suggest that he should make a trial of these other methods of " flitting " before questioning the figures given (the words " pulling-up " are also being used instead of " moving " or " flitting "). The largest output on the belt in any one day of 10 hours, namely, 140 tons, was obtained in a seam 2 feet 8 inches in thickness. The depth of cut cannot be given accurately, as the face was a hand-got face, but the average advance was from 7 to 7½ feet per day.

An output of 50 to 60 tons per hour for a conveyor to handle is quite within reason: Mr. Watson Smith stated that he had obtained a delivery of 1½ tons per minute from a conveyor.

With reference to the first figures given in Appendix II., he stated that the Institute would like to have information as to what was done before conveyors were put in. The reply is "nil," as this seam was opened out with conveyors from the commencement. It does not follow that, if Mr. Wroe is not getting certain results, it is impossible for other collieries to obtain them.

The question of keeping one face in advance of the other, and of driving headings in advance of the working-face, must be decided by the conditions of roof, etc. Undoubtedly, my experience has been that where the conditions are suitable advantages have been gained by this method; but where conditions exist similar to those described by Mr. Wroe, the alternative method which he uses is the most satisfactory.

Wth reference to Mr. Sutcliffe's remarks on the installation of conveyors and the attitude of the men, this is a question for the management of the pit. I know of a large number of cases where conveyors have been installed and have operated entirely satisfactorily from the start. In other cases, of course, trouble due to labour has been very considerable. In two cases I know of, it has necessitated taking the conveyors out of the pit.

Mr. Ensor states that the expressing of output in the ratio "tons per man" is liable to cause trouble to the colliery manager. I am sorry that I should have added to the already large burden which a colliery manager has nowadays to bear. If Mr. Ensor will let me know what further particulars he requires in connexion with any of the installations mentioned, I will endeavour to supply them to him personally. In every instance the figures that have been given to me have been supplied by the management of the colliery concerned, and what I have asked for has been " the output per man employed filling coal on the face before and after the use of conveyors." The figures given in almost every case are comparative only, so that the total number of men employed is not so essential. The figures which I have put forward have been averages given on average days, and not on selected days on which the output was large. In all cases the figures can be confirmed by visits to the installations to which reference is made.

I am afraid that nowadays a large number of colliery managers do not agree with Mr. Ensor when he states that " where a tub can go no conveyors will be put in." The number of conveyors in use is increasing, not decreasing. In nearly all the cases I cited the conveyors have been installed within the last three years.

I am trying to arrange for Mr. Wroe and Mr. Ensor to accompany me on a visit to the Durham colliery, as the figures referring to this colliery have been questioned.

Mr. H. Watson Smith gives an example of a method which should be avoided in attempting to sell conveyors or any other class of machines.

With regard to Mr. Lloyd's statements, I have already replied to the various points connected with the question of the number of men employed at the face, and am glad that he has brought this matter forward.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM SEPT. 29TH TO NOV. 2ND, 1918, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of		Magnetic character.	Intervals in hours (Greenwich mean time).												
Week.	Month.		0h. to 2h.	2h. to 4h.	4h. to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h.	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
			14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
Sun. ...	Sept. 29	1	43′·0	45′·5	46′·0	45′·0	45′·0	48′·5	54′·0	55′·0	51′·0	47′·5	42′·0	46′·5	47′·5
Mon. ...	30	2	44·5	39·5	45·0	44·5	44·0	49·0	53·5	53·5	46·0*	47·0	44·0	46·0	46·5
Tues. ...	Oct. 1	2	46·0	46·0	45·5	45·5	46·0	50·5	54·5	53·0	49·0	46·5*	41·0*	46·5*	47·5
Wed. ...	2	1	46·0	47·5	49·0	44·5	44·0	50·0	54·5	51·5	47·0	47·0	45·0	47·5	48·0
Thur. ...	3	1	48·5	47·5	49·5	45·5	45·0	49·5	54·5	54·5	46·0	46·0	45·5	45·0	48·0
Fri. ...	4	1	48·5	46·5	47·5	45·5	45·0	48·5	55·0	53·5	49·5	45·5	45·0	47·0	48·0
Sat. ...	5	2	46·5	47·5	47·5	45·0	43·5	48·0	54·5	56·0	52·0	47·0*	39·5*	44·5*	47·5
Sun. ...	6	1	48·5	47·5	48·5	45·5	43·5	48·5	53·0	53·0	50·0	47·0	44·0	46·0	48·0
Mon. ...	7	1	48·5	48·0	47·0	46·0	44·5	49·0	53·0	52·5	47·0	46·5	43·5	46·5	47·5
Tues. ...	8	2	48·0	49·0	47·0	47·5	46·5	52·0	56·5	55·5*	52·0*	42·0*	42·5*	37·0*	48·0
Wed. ...	9	2	38·0*	41·5*	46·0*	43·5	44·0	50·5	56·5	55·5	51·5	49·5	48·0	48·5	47·5
Thur. ...	10	0	48·0	48·0	48·0	46·0	45·0	50·0	54·0	51·5	49·0	46·0	46·5	47·0	48·5
Fri. ...	11	0	47·5	47·5	47·0	45·5	45·0	50·5	54·0	52·5	50·0	49·0	47·0	47·0	48·5
Sat. ...	12	0	47·5	47·5	46·5	45·0	44·5	48·5	52·0	51·5	49·5	47·5	47·5	47·5	48·0
Sun. ...	13	0	46·0	46·5	47·0	45·5	43·5	48·0	52·0	51·5	49·5	48·0	47·5	47·0	47·5
Mon. ...	14	0	47·0	47·0	46·5	45·0	44·5	48·5	53·0	52·5	49·5	48·5	47·0	47·0	48·0
Tues. ...	15	1	47·0	47·0	48·0	46·5	45·0	52·0	57·5	56·0	53·5	49·0	46·5	46·5	49·5
Wed. ...	16	2	47·0	46·5*	54·5*	53·5*	51·0*	58·0*	57·0*	55·0*	51·5*	46·0*	46·5*	48·0	51·0
Thur. ...	17	2	48·0	51·0	50·0	46·5	46·0	51·0	55·0	48·5	48·5	43·5*	42·0*	45·5	48·0
Fri. ...	18	1	47·5	48·0	47·5	49·5	49·0	52·5	53·0	50·0	47·0	45·5	44·5	45·5	48·5
Sat. ...	19	2	47·0	47·5	48·5	46·0	45·5	51·5	56·0	53·5	50·5	48·0	44·0*	36·5*	48·0
Sun. ...	20	2	43·5*	48·5*	46·5	45·5	49·5	53·0	52·5	50·0	47·5	45·5	45·5	45·0	48·0
Mon. ...	21	1	42·5	44·5	46·0	45·0	43·5	49·0	53·5	53·0	52·5	49·0	44·5	44·0	47·5
Tues. ...	22	0	44·5	44·0	45·5	45·5	46·0	50·5	54·5	52·5	48·5	47·0	46·0	44·0	47·5
Wed. ...	23	0	46·0	47·5	47·5	44·5	45·5	52·0	55·5	54·0	49·5	47·0	43·5	41·0	47·5
Thur. ...	24	0	42·5	43·0	44·0	45·0	46·0	51·5	54·5	51·5	49·0	48·0	47·0	45·5	47·5
Fri. ...	25	1	43·5	45·5	46·5	45·5	44·0	48·5	51·5	53·5	50·5	48·5	47·0	44·0	47·5
Sat. ...	26	0	44·0	46·0	45·5	45·0	45·0	49·0	52·0	49·5	48·0	47·5	47·0	46·5	47·0
Sun. ...	27	0	46·0	46·5	47·0	46·0	44·5	48·5	51·5	50·0	48·0	47·5	46·5	45·5	47·5
Mon. ...	28	2	47·0	47·0	46 0	45·5	44·5	49·5	55·0	53·5	48·5*	48·0	46·5	46·0	48·0
Tues. ...	29	0	46·5	46·5	46·0	45·0	44·5	48·5	51·5	50·5	48·5	47·0	44·5	42·0	46·5
Wed. ...	30	0	46·5	47·5	46·0	45·0	44·5	49·5	52·0	50·0	48·0	47·0	46·5	42·5	47·0
Thur. ...	31	1	43·5	44·5	45·0	48·0	49·5	51·5	54·5	52·0	48·5	43·5	43·0	47·0	47·5
Fri. ..	Nov. 1	1	46·5	47·5	46·0	44·5	44·5	49·0	52·0	50·0	48·5	47·0	44·0	46·0	47·0
Sat. ...	2	1	47·5	48·0	47·0	45·0	45·0	49·0	51·0	50·0	47·0	47·0	46·0	45·5	47·5

Diurnal Inequality (i.e., departure from mean value for day).

	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.
October, 1917 ...	-1′·5	-1′·4	-1′·1	-0′·8	-0′·8	-1′·8	-3′·5	-5′·1	-4′·7	-2′·2	+1′·5	+4′·4
September, 1918 ...	-1·2	-1·7	-2·4	-2·9	-2·9	-2·9	-3·6	-3·8	-2·3	+0·4	+4·3	+6·6
September, 1917 ...	-1·2	-1·5	-1·8	-2·1	-2·4	-3·4	-5·0	-6·0	-5·1	-2·2	+2·6	+5·5
	13h.	14h	15h.	16h.	17h.	18h.	19h	20h.	21h.	22h.	23h.	24h.
October, 1917 ...	+5 ·5	+5′·5	+4′·5	+2′·9	+2′·1	+1′·3	+0′·5	-0′·1	-0′·7	-1′·2	-1′·5	-1′·8
September, 1918 ..	+7·1	+6·8	+4·8	+2·5	+0·9	-0·1	-1·0	-1·4	-1 7	-1·9	-1·9	-1·5
September, 1917 ...	+7·1	+5 5	+4·9	+3·2	+2·0	+1·1	+0·5	+0·1	-0·2	-0·6	-0·9	-1·2

* Large disturbances during this interval.

Mean Value for Month.

October, 1917.	September, 1918.	September, 1917.
14° 57′·5.	14° 48′·6.	14° 58′·4.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G.M.T.

Character "0" means a day wholly free from any but small disturbances.

" "1" " " part or all of which is moderately or considerably disturbed.

" "2" " " part or all of which is highly disturbed.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD AT THE HERIOT-WATT COLLEGE, EDINBURGH, OCTOBER 5TH, 1918.

MR. DAVID M. MOWAT, PRESIDENT, IN THE CHAIR.

DISCUSSION OF MR. R. W. DRON'S PAPER ON "THE OCCURRENCE OF COKING COAL IN SCOTLAND."*

Mr. JAMES HAMILTON (Glasgow): Mr. Dron's conclusions as to the origin of coking coal are somewhat encouraging. For example, the author suggests the possibility of coking coal being produced from the action of igneous rock on a coal-seam. If this be so, it rather points to the possibility of coking any seam of coal. The only effect of an igneous rock on a seam lying below it must be that of heat. In such a case, there is no possibility of gases affecting the constitution of the coal-seam, as might happen if the igneous rock lay underneath the seam. What can be done by Nature in this way rather gives encouragement to the hope that the same result may be attained by the manufacturing process. Certainly there should be some chance of effecting this change artificially and producing the same result. There is, of course, no real comparison between the two processes, but provided the same intensity of heat is obtained through similar gradations over a shorter time, what Nature does by a slower process might be artificially produced—that is, coke from any coal-seam. I suppose that there is no doubt that heat alone can convert ordinary coal into anthracite, and there are quite a number of cases on record where a change has been effected in a very short time. In the Stirling district it is quite evident that the character of the coal changes the farther away one goes from the underlying igneous rock.

Mr. R. W. DRON (Glasgow): As mentioned by Mr. Balfour Sneddon (vol. lv., page 69), the effect of intrusive whinstone on oil-shale is to drive off the volatile matter. It is possible that in some areas in Scotland, lying to the west of the oil-shale fields, the volatile matters thus driven off may be found as crude oil in overlying beds of sandstone. In several Scottish mines crude oil has been found in small quantities, and it seems likely that this has been formed by some such action. Mr. D. M. Mowat and others raise a point about the average percentage of moisture contained in coals of the various formations. In order to throw some further light on this, I have prepared the following table from the list of coals analysed by Dr. Gray:—

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., pages 61 and 145.

AVERAGE PERCENTAGE OF MOISTURE CONTAINED IN COALS OF THE VARIOUS FORMATIONS.

Formation	District.	No. of Samples.	Moisture Average.	Coking Index Average.
			Per cent	
Carboniferous Limestone	From north of Glasgow to Stirling	42	2·45	22
,, ,,	Carluke to Bo'ness ...	31	4·41	12·5
,, ,,	Fife	30	6·49	9
,, ,,	Mid-Lothian	16	7·94	Below 8
Coal-Measures	Central Coalfield ...	194	5·90	10
,, ...	Fife and Alloa ..	9	9.65	Below 8
,, ...	Mid-Lothian	6	9·44	7

These figures show interesting results, but it must be noted that the samples dealt with were to a large extent selected from those seams which were supposed to have some coking properties. They do not represent a true average of all the seams in each district.

With regard to Mr. John R. Gordon's question (vol. lv., page 145), I am not at present aware of any coking coal-seam in Scotland about which it can be said with certainty that it has not been affected by whinstone, but the Kiltongue Coal Seam of Motherwell and Larkhall is rather doubtful. They are cases in which an individual seam is affected beneficially by the proximity of whinstone, but I have not available the exact data to enable me to cite particular instances. The alteration of the coal-seams between Possil and Kilsyth is a good general example. Mr. David Ferguson (vol. lv., page 145) expresses the view that the qualities of the Kilsyth Main Coal are quite independent of any intrusive agency. At the Drumbreck Pit the Kilsyth quartz dolerite sill lies a few fathoms below the Index Limestone, and is thus above the coal-seams. There is no direct evidence of an underlying sill, but the presence of the overlying sill may be sufficient to account for the coking qualities of the seams. As Mr. James Hamilton remarks, the only effect of an igneous rock on a seam lying below it must be that of heat. Research-work on the lines indicated by Mr. Hamilton would be very valuable, and the suggestion should be placed before the Fuel Research Board.

On page 63 of Vol. LIV., lines 10, 18, 19, and 21, "grams" has been inadvertently printed as "grains."

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD AT THE HERIOT-WATT COLLEGE, EDINBURGH, OCTOBER 5TH, 1918.

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Mr. R. W. DRON (Glasgow): As mentioned by Mr. Balfour Sneddon (vol. lv., page 69), the effect of intrusive whinstone on oil-shale is to drive off the volatile matter. It is possible that in some areas in Scotland, lying to the west of the oil-shale fields, the volatile matters thus driven off may be found as crude oil in overlying beds of sandstone. In several Scottish mines crude oil has been found in small quantities, and it seems likely that this has been formed by some such action. Mr. D. M. M[illegible] and [illegible] raise a point about the average percentage of moisture [illegible] in coals of the various formations. In [illegible] light on this, I have prepared the following table [illegible] coals analysed by Dr. Gray:—

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., pages 61 and 145.

AVERAGE PERCENTAGE OF MOISTURE CONTAINED [illegible] FORMATIONS.

Formation	District.	No. of samples	[illegible]	[illegible]
Carboniferous Limestone	From north of Glasgow to Stirling	[illegible]	[illegible]	[illegible]
,, ,,	Carluke to Bo'ness	31	[illegible]	[illegible]
,, ,,	Fife	36	[illegible]	[illegible]
,, ,,	Mid-Lothian	16	[illegible]	[illegible]
Coal-Measures ...	Central Coalfield ..	194	[illegible]	[illegible]
,, ...	Fife and Alloa ..	9	[illegible]	[illegible]
,, ...	Mid-Lothian	6	[illegible]	[illegible]

These figures show interesting results, but [illegible] that the samples dealt with were to a large extent [illegible] from those seams which were supposed to have some coking [illegible]. They do not represent a true average of all the seams [illegible] district.

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DISCUSSION OF MR. STEWART CHAMBERS'S PAPER ON "THE REPAIR OF A CIRCULAR SHAFT OF SMALL DIAMETER."*

The **PRESIDENT** (Mr. D. M. Mowat): The ordinary way to repair a shaft that had collapsed in this way would have been to start from the bottom, but that would have exposed the workmen to serious risk from falling *débris*. In a case of arching in a pit-bottom under similar circumstances, a fall took place, 36 feet high, the arch being 26 feet wide. It was the greatest relief to all connected with the undertaking when the first ring of brickwork was got into the shaft, because until then there was no refuge-hole to go to. The operation described by Mr. Chambers appealed to me as a somewhat similar experience to the one just mentioned. If work had been started from the bottom, there would have been no escape for the men in the event of a fall of *débris*. It would not have mattered how small the piece was that fell; it would almost certainly have caused a fatal accident if it struck anyone in the course of its descent.

Mr. **RICHARD KIRKBY** (Wemyss): With regard to the boxes and barrels used to fill up the cavity, I wonder whether something else could not have been obtained to take their place. Probably they were the best filling that could have been used, as stones and refuse of that kind might have been too heavy to take down with ease. As there is concrete in the sides of the walls, I do not think that the boxes and barrels will give much trouble.

The **PRESIDENT**: I think that in an operation of this kind an arrangement should be made to make the lining tube bigger than actually required, so as to allow for want of alignment. In a sinking where the cylinder gets often out of plumb it is good practice to make it larger than is actually required, so as to get a straight line through. The paper contains many practical hints which will be of value to others faced with similar difficulties.

The further discussion of the paper was adjourned.

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., page 203.

THE ECONOMY OF BRIQUETTING SMALL COAL.

By J. A. YEADON.

Introduction.—Before entering into a full consideration of the immediate subject of the paper, it might be well to mention briefly two other important questions which are inseparably connected with it, namely, the conservation of coal and the utilization of waste materials. "Coal" in this case includes bituminous, non-bituminous, and anthracitic coal, and also coke-breeze.

Conservation of Coal.—Never before in the history of this country has this subject assumed or obtained the importance it now commands. Our industrial wealth depends very largely on an abundant supply of coal; this country is rich in its ample possession of this mineral; and it is our duty to posterity to ensure that we "conserve" this great asset by striving to secure the best results from every ton of coal brought to the surface.

Utilization of Waste Materials.—All trades and manufactures in this country are (or should be) closely interested in this question, which is bound to increase in importance in the future. It will be one of vital interest in our inevitable competition with other leading nations after the conclusion of peace. So far as fuel is concerned, we have hitherto been *one* of the most wasteful, if not *the* most wasteful, nation in the world. We allowed, and are still allowing, immense quantities of mined small coal to remain in our pits as not worth bringing to the surface. At the present time large quantities of usable small coal are lying in heaps at bank as comparatively useless and unsaleable, there to deteriorate in quality or to break out into spontaneous combustion, and thus to become a nuisance and a danger to those in the immediate neighbourhood. The small coke-breeze from coke-ovens and gas-works has also been allowed to accumulate in vast heaps as a useless material, or has been used for ballast on the railways, and great heaps of "slimes" from coal-washers are still allowed to accumulate as waste material. Every ounce of the above material could be utilized profitably, given a suitable process and proper machinery. Very much of this waste might have been avoided in recent years if more sympathetic interest and practical help had been forthcoming from coal authorities towards those who, knowing all these facts, were prepared and ready to undertake special enterprises to meet and overcome successfully the present abnormal and unprecedented deficit in our coal supplies.

Economy of Briquetting Small Coal.—The following advantages can be claimed for coal-briquettes when properly made:—

(*a*) According to Prof. Goss, the calorific power of good quality briquettes is higher than that of the coal from which they are made, when pitch is used as the agglomerant.

(*b*) Briquettes thus produced are unaffected by exposure to the weather, and suffer less deterioration than the coal itself.

(*c*) Briquettes produced from small coal can be made suitable for any purpose for which coal is ordinarily used for steam-raising or heating, the one exception being for smelting in blast-furnaces.

(*d*) Under normal conditions, and with suitable and the latest improved processes and machinery, any ordinary small coal can be converted into marketable briquettes, and leave a satisfactory profit to the makers. Good qualities command the same price per ton as large coal.

It is the exception *in this country* to find a colliery provided with a briquetting plant. Before the war, it was the exception to come across any leading Continental colliery company *not provided* with a suitable briquetting works.

Briquetting has been described as the method or process by which small coal, when mixed with a certain proportion of pitch (or other suitable agglomerant), is converted into compressed blocks of fuel called "briquettes." So far, pitch easily holds the field as the most suitable agglomerant for this purpose. It is a production from the distillation of gas-tar, or from blast-furnaces where, as in Scotland, coal is largely used for smelting. Pitch has the following important qualities: (1) it helps efficiency; (2) it adds no "ash"; and (3) the briquettes so made are weather-proof.

A number of other agglomerants have been tried, but without success. Various attempts have also been made to dispense with an agglomerant and to produce briquettes from small coal only by applying enormous pressure by means of very powerful machinery; but, so far, not one of these methods has proved a commercial success. When obtainable at a reasonable price, pitch still holds the field. At the present time there are large accumulations of pitch in this country simply waiting for a suitable process for its utilization. One of the best of these is decidedly the manufacture of coal-briquettes.

Method of Manufacture.—Briefly, the process of briquetting consists in the mixing of the small coal with a suitable proportion of pitch, these ingredients being then thoroughly ground together to the requisite fineness and subjected to the action of injected superheated steam, which softens the pitch and makes it plastic. The heated mixture is then fed or charged into the briquette press, where it is moulded, powerfully compressed, and converted into finished briquettes ready for delivery into the wagons, or for stacking on the open ground. When cold, they are as hard as coal, and are then ready for shipment or use.

The proportion of pitch required for agglomeration varies according to the nature and quality of the small coal used, ranging generally from 7 to 10 per cent. If the coal is wet, or if it contains a large proportion of ash, more pitch is required. The drier, cleaner, and more bituminous the coal, the less pitch is required.

Rectangular and "Ovoid" Forms of Briquettes.—The briquettes produced in this country are, generally speaking, of two forms or shapes, the rectangular and the "ovoid." Until very recent years, nearly the whole of these briquettes were rectangular, this being the most suitable shape for shipment, as the greatest tonnage weight per cubic yard can be stacked in the hold of the ship. The best quality of rectangular briquettes are those which are compressed from both sides, which gives a more even solidity to the briquettes, and also "rounds off" all the edges on both faces of the briquettes, thus minimizing breakage in handling. This system, first introduced by Messrs. Yeadon & Company, Leeds, over forty years ago, was soon copied, and is now adopted almost universally by the leading Continental makers of briquetting machines.

The first briquetting plant in Scotland on this system was erected thirty-two years ago for Messrs. William Baird & Company, Limited, at their Lugar Works, and their example was soon followed by a number of other leading Scotch firms. At the present time a briquetting plant on this system is working at the Polmaise Colliery, Stirling, with an output of 400 tons per day of 10 hours, nearly the whole of the production being for export. The rectangular briquettes produced in Scotland vary in weight from 3 to 14 pounds each, the larger sizes being for marine and locomotive consumption, and the smaller for domestic or manufacturing use. Briquettes intended for general shipment should contain not more than 10 per cent. of ash in the coal used; for best qualities, suitable for naval requirements, 8 per cent. is the maximum.

At Cramlington Colliery, Northumberland, a briquette plant is at work producing both rectangular and ovoid briquettes. Another similar plant is now being erected for the Manor Powis Company, near Stirling.

The ovoid form of briquette is rapidly being adopted in this country. They have been made in America and on the Continent

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,

Held at the University, St. George's Square, Sheffield,
July 25th, 1918.

Mr. W. D. LLOYD, President, in the Chair.

DISCUSSION OF MR. H. C. JENKINS'S PAPER ON "UNDERGROUND CONVEYORS."*

Mr. H. C. Jenkins (Sheffield) wrote, in reply to the previous discussion (Vol. LV., page 116): In one instance in Scotland the datal men filled 15 tons per man within one week of the installation of the conveyors, and ten men averaged 140 to 150 tons per shift on 100 consecutive days.

In reply to Mr. Drinnan, it would, perhaps, be within the scope of another paper to state cases where conveyors have been a failure, although case No. 3 in Appendix I. records one failure. I am sure that it is agreed that it would be useless to cite as typical the results obtained with conveyors where the conditions are not suitable. Several instances have occurred in which seams have been inspected and reported as unfavourable for the installation of conveyors. I do not agree with Mr. Drinnan that conveyors are installed only in thin seams, as their use is now extending to much thicker seams. The difficulty mentioned in his remarks regarding the roof must, of course, be considered and taken into account when introducing conveyors. The facility or otherwise of dismantling, removing, and re-erecting, or "moving-up" conveyors varies very much, depending greatly on the system adopted by the management, the roof conditions, the thickness and the inclination of the seam, and the type of conveyor. Two to 2½ hours for two men to move any type of conveyor should not be taken as an average time, but belt-conveyors are being moved up regularly in this time.

Mr. Wroe asks for an explanation of several points mentioned in the paper. Mr. Wroe has had such extensive experience in the use of conveyors that I am glad to note that he agrees with some of the statements made in the paper. Further details regarding the Durham colliery equipment, with reference to certain facts questioned by Mr. Wroe, are as follows:—

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., pages 2 and 116.

In the first case, Mr. Wroe makes a mistake in assuming that I referred to a machine-cut face. The figures given are for hand-got coal. The average height of the seam in which an output of 400 tons was maintained in 10 hours with tubs of 8 cwt. capacity was 2 feet 8 inches, and the number of hewers employed at the face was nineteen.

The second point raised by Mr. Wroe referred to the operation of " flitting " or " moving-up." There are six men on the face altogether during this operation; two of them move the conveyor forward within the time stated, and then assist the other four in drawing and setting timber.

Another point which Mr. Wroe omitted to notice was that the belt is cut into 20 to 25-yard lengths, compared with Mr. Wroe's 90-yard lengths. I stated in the paper that by adopting these lengths the " flitting-time " was reduced by 3 hours or more.

It may be of interest to know that, in order to overcome the variations of both roof and coal, it was necessary to alter continually the distance of the chocks from the face, and also vary considerably the amount of small coal placed under the chocks to allow the roof weight to act upon the coal-face so as to " work " it, and that owing to these circumstances alone has it been possible to keep the output at all regular.

Another point which Mr. Wroe has probably not noticed is that at this colliery small stands are used for carrying wooden rollers, whereas Mr. Wroe uses wooden rollers set into props, which take more time to set, so that his statement that such a rapid "change-over" is an impossibility would be quite correct if a 90-yard belt in one piece was being used. I would suggest that he should make a trial of these other methods of " flitting " before questioning the figures given (the words " pulling-up " are also being used instead of " moving " or " flitting "). The largest output on the belt in any one day of 10 hours, namely, 140 tons, was obtained in a seam 2 feet 8 inches in thickness. The depth of cut cannot be given accurately, as the face was a hand-got face, but the average advance was from 7 to 7½ feet per day.

An output of 50 to 60 tons per hour for a conveyor to handle is quite within reason: Mr. Watson Smith stated that he had obtained a delivery of 1½ tons per minute from a conveyor.

With reference to the first figures given in Appendix II., he stated that the Institute would like to have information as to what was done before conveyors were put in. The reply is "nil," as this seam was opened out with conveyors from the commencement. It does not follow that, if Mr. Wroe is not getting certain results, it is impossible for other collieries to obtain them.

The question of keeping one face in advance of the other, and of driving headings in advance of the working-face, must be decided by the conditions of roof, etc. Undoubtedly, my experience has been that where the conditions are suitable advantages have been gained by this method; but where conditions exist similar to those described by Mr. Wroe, the alternative method which he uses is the most satisfactory.

Wth reference to Mr. Sutcliffe's remarks on the installation of conveyors and the attitude of the men, this is a question for the management of the pit. I know of a large number of cases where conveyors have been installed and have operated entirely satisfactorily from the start. In other cases, of course, trouble due to labour has been very considerable. In two cases I know of, it has necessitated taking the conveyors out of the pit.

Mr. Ensor states that the expressing of output in the ratio "tons per man" is liable to cause trouble to the colliery manager. I am sorry that I should have added to the already large burden which a colliery manager has nowadays to bear. If Mr. Ensor will let me know what further particulars he requires in connexion with any of the installations mentioned, I will endeavour to supply them to him personally. In every instance the figures that have been given to me have been supplied by the management of the colliery concerned, and what I have asked for has been " the output per man employed filling coal on the face before and after the use of conveyors." The figures given in almost every case are comparative only, so that the total number of men employed is not so essential. The figures which I have put forward have been averages given on average days, and not on selected days on which the output was large. In all cases the figures can be confirmed by visits to the installations to which reference is made.

I am afraid that nowadays a large number of colliery managers do not agree with Mr. Ensor when he states that " where a tub can go no conveyors will be put in." The number of conveyors in use is increasing, not decreasing. In nearly all the cases I cited the conveyors have been installed within the last three years.

I am trying to arrange for Mr. Wroe and Mr. Ensor to accompany me on a visit to the Durham colliery, as the figures referring to this colliery have been questioned.

Mr. H. Watson Smith gives an example of a method which should be avoided in attempting to sell conveyors or any other class of machines.

With regard to Mr. Lloyd's statements, I have already replied to the various points connected with the question of the number of men employed at the face, and am glad that he has brought this matter forward.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM SEPT. 29TH TO NOV. 2ND, 1918, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of		Magnetic character.	Intervals in hours (Greenwich mean time).												
Week.	Month.		0h. to 2h.	2h. to 4h.	4h. to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h.	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
			14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
Sun. ...	Sept. 29	1	43′·0	45′·5	46′·0	45′·0	45′·0	48′·5	54′·0	55′·0	51′·0	47′·5	42′·0	46′·5	47′·5
Mon. ...	30	2	44·5	39·5	45·0	44·5	44·0	49·0	53·5	53·5	46·0*	47·0	44·0	46·0	46·5
Tues. ...	Oct. 1	2	46·0	46·0	45·5	45·5	46·0	50·5	54·5	53·0	49·0	46·5*	41·0*	46·5*	47·5
Wed. ...	2	1	46·0	47·5	49·0	44·5	44·0	50·0	54·5	51·5	47·0	47·0	45·0	47·5	48·0
Thur. ...	3	1	48·5	47·5	49·5	45·5	45·0	49·5	54·5	54·5	46·0	46·0	45·5	45·0	48·0
Fri. ...	4	1	48·5	46·5	47·5	45·5	45·0	48·5	55·0	53·5	49·5	45·5	45·0	47·0	48·0
Sat. ...	5	2	46·5	47·5	47·5	45·0	43·5	48·0	54·5	56·0	52·0	47·0*	39·5*	44·5*	47·5
Sun. ...	6	1	48·5	47·5	48·5	45·5	43·5	48·5	53·0	53·0	50·0	47·0	44·0	46·0	48·0
Mon. ...	7	1	48·5	48·0	47·0	46·0	44·5	49·0	53·0	52·5	47·0	46·5	43·5	46·5	47·5
Tues. ...	8	2	48·0	49·0	47·0	47·5	46·5	52·0	56·5	55·5*	52·0*	42·0*	42·5*	37·0*	48·0
Wed. ...	9	2	38·0*	41·5*	46·0*	43·5	44·0	50·5	56·5	55·5	51·5	49·5	48·0	48·5	47·5
Thur. ...	10	0	48·0	48·0	48·0	46·0	45·0	50·0	54·0	51·5	49·0	46·0	46·5	47·0	48·5
Fri. ...	11	0	47·5	47·5	47·0	45·5	45·0	50·5	54·0	52·5	50·0	49·0	47·0	47·0	48·5
Sat. ...	12	0	47·5	47·5	46·5	45·0	44·5	48·5	52·0	51·5	49·5	47·5	47·5	47·5	48·0
Sun. ...	13	0	46·0	46·5	47·0	45·5	43·5	48·0	52·0	51·5	49·5	48·0	47·5	47·0	47·5
Mon. ...	14	0	47·0	47·0	46·5	45·0	44·5	48·5	53·0	52·5	49·5	48·5	47·0	47·0	48·0
Tues. ...	15	1	47·0	47·0	48·0	46·5	45·0	52·0	57·5	56·0	53·5	49·0	46·5	46·5	49·5
Wed. ...	16	2	47·0	46·5*	54·5*	53·5*	51·0*	58·0*	57·0*	55·0*	51·5*	46·0*	46·5*	48·0	51·0
Thur. ...	17	2	48·0	51·0	50·0	46·5	46·0	51·0	55·0	48·5	48·5	43·5*	42·0*	45·5	48·0
Fri. ...	18	1	47·5	48·0	47·5	49·5	49·0	52·5	53·0	50·0	47·0	45·5	44·5	45·5	48·5
Sat. ...	19	2	47·0	47·5	48·5	46·0	45·5	51·5	56·0	53·5	50·5	48·0	44·0*	36·5*	48·0
Sun. ...	20	2	48·5*	48·5*	46·5	45·5	49·5	53·0	52·5	50·0	47·5	45·5	45·5	45·0	48·0
Mon. ...	21	1	42·5	44·5	46·0	45·0	43·5	49·0	53·5	53·0	52·5	49·0	44·5	44·0	47·5
Tues. ...	22	0	44·5	44·0	45·5	45·5	46·0	50·5	54·5	52·5	48·5	47·0	46·0	44·0	47·5
Wed. ...	23	0	46·0	47·5	47·5	44·5	45·5	52·0	55·5	54·0	49·5	47·0	43·5	41·0	47·5
Thur. ...	24	0	42·5	43·0	44·0	45·0	46·0	51·5	54·5	51·5	49·0	48·0	47·0	45·5	47·5
Fri. ...	25	1	43·5	45·5	46·5	45·5	44·0	48·5	51·5	58·5	50·5	48·5	47·0	44·0	47·5
Sat. ...	26	0	44·0	46·0	45·5	45·0	45·0	49·0	52·0	49·5	48·0	47·5	47·0	46·5	47·0
Sun. ...	27	0	46·0	46·5	47·0	46·0	44·5	48·5	51·5	50·0	48·0	47·5	46·5	45·5	47·5
Mon. ...	28	2	47·0	47·0	46·0	45·5	44·5	49·5	55·0	53·5	48·5*	48·0	46·5	46·0	48·0
Tues. ...	29	0	46·5	46·5	46·0	45·0	44·5	48·5	51·5	50·5	48·5	47·0	44·5	42·0	46·5
Wed. ...	30	0	46·5	47·5	46·0	45·0	44·5	49·5	52·0	50·0	48·0	47·0	46·5	42·5	47·0
Thur. ...	31	1	43·5	44·5	45·0	48·0	49·5	51·5	54·5	52·0	48·5	43·5	43·0	47·0	47·5
Fri. ..	Nov. 1	1	46·5	47·5	46·0	44·5	44·5	49·0	52·0	50·0	48·5	47·0	44·0	46·0	47·0
Sat. ...	2	1	47·5	48·0	47·0	45·0	45·0	49·0	51·0	50·0	47·0	47·0	46·0	45·5	47·5

Diurnal Inequality (*i.e.*, *departure from mean value for day*).

	1h.	2h.	3h.	4h.	5h.	6h	7h.	8h.	9h.	10h.	11h.	12h.
October, 1917 ...	-1′·5	-1′·4	-1′·1	-0′·8	-0′·8	-1′·8	-3′·5	-5′·1	-4′·7	-2′·2	+1′·5	+4′·4
September, 1918 ...	-1·2	-1·7	-2·4	-2·9	-2·9	-2·9	-3·6	-3·8	-2·3	+0·4	+4·3	+6·6
September, 1917 ...	-1·2	-1·5	-1·8	-2·1	-2·4	-3·4	-5·0	-6·0	-5·1	-2·2	+2·6	+5·5

	13h.	14h	15h.	16h.	17h.	18h.	19h	20h.	21h.	22h.	23h.	24h.
October, 1917 ...	+5′·5	+5′·5	+4′·5	+2′·9	+2′·1	+1′·3	+0′·5	-0′·1	-0′·7	-1′·2	-1′·5	-1′·8
September, 1918 ..	+7·1	+6·3	+4·8	+2·5	+0·9	-0·1	-1·0	-1·4	-1·7	-1·9	-1·9	-1·5
September. 1917 ...	+7·1	+5·5	+4·9	+3·2	+2·0	+1·1	+0·5	+0·1	-0·2	-0·6	-0·9	-1·2

* Large disturbances during this interval.

Mean Value for Month.

October, 1917.	September, 1918.	September, 1917.
14° 57′·5.	14° 48′·6.	14° 58′·4.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G.M.T.

Character "0" means a day wholly free from any but small disturbances.

„ "1" „ „ part or all of which is moderately or considerably disturbed.

„ "2" „ „ part or all of which is highly disturbed.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD AT THE HERIOT-WATT COLLEGE, EDINBURGH, OCTOBER 5TH, 1918.

MR. DAVID M. MOWAT, PRESIDENT, IN THE CHAIR.

DISCUSSION OF MR. R. W. DRON'S PAPER ON "THE OCCURRENCE OF COKING COAL IN SCOTLAND."*

Mr. JAMES HAMILTON (Glasgow): Mr. Dron's conclusions as to the origin of coking coal are somewhat encouraging. For example, the author suggests the possibility of coking coal being produced from the action of igneous rock on a coal-seam. If this be so, it rather points to the possibility of coking any seam of coal. The only effect of an igneous rock on a seam lying below it must be that of heat. In such a case, there is no possibility of gases affecting the constitution of the coal-seam, as might happen if the igneous rock lay underneath the seam. What can be done by Nature in this way rather gives encouragement to the hope that the same result may be attained by the manufacturing process. Certainly there should be some chance of effecting this change artificially and producing the same result. There is, of course, no real comparison between the two processes, but provided the same intensity of heat is obtained through similar gradations over a shorter time, what Nature does by a slower process might be artificially produced—that is, coke from any coal-seam. I suppose that there is no doubt that heat alone can convert ordinary coal into anthracite, and there are quite a number of cases on record where a change has been effected in a very short time. In the Stirling district it is quite evident that the character of the coal changes the farther away one goes from the underlying igneous rock.

Mr. R. W. DRON (Glasgow): As mentioned by Mr. Balfour Sneddon (vol. lv., page 69), the effect of intrusive whinstone on oil-shale is to drive off the volatile matter. It is possible that in some areas in Scotland, lying to the west of the oil-shale fields, the volatile matters thus driven off may be found as crude oil in overlying beds of sandstone. In several Scottish mines crude oil has been found in small quantities, and it seems likely that this has been formed by some such action. Mr. D. M. Mowat and others raise a point about the average percentage of moisture contained in coals of the various formations. In order to throw some further light on this, I have prepared the following table from the list of coals analysed by Dr. Gray:—

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., pages 61 and 145.

Average Percentage of Moisture contained in Coals of the various Formations.

Formation	District.	No. of Samples.	Moisture Average.	Coking Index Average.
			Per cent	
Carboniferous Limestone	From north of Glasgow to Stirling	42	2·45	22
,, ,,	Carluke to Bo'ness ...	31	4·41	12·5
,, ,,	Fife	30	6·49	9
,, ,,	Mid-Lothian	16	7·94	Below 8
Coal-Measures ...	Central Coalfield ..	194	5·90	10
,, ...	Fife and Alloa ..	9	9.65	Below 8
,, ...	Mid-Lothian	6	9·44	7

These figures show interesting results, but it must be noted that the samples dealt with were to a large extent selected from those seams which were supposed to have some coking properties. They do not represent a true average of all the seams in each district.

With regard to Mr. John R. Gordon's question (vol. lv., page 145), I am not at present aware of any coking coal-seam in Scotland about which it can be said with certainty that it has not been affected by whinstone, but the Kiltongue Coal Seam of Motherwell and Larkhall is rather doubtful. They are cases in which an individual seam is affected beneficially by the proximity of whinstone, but I have not available the exact data to enable me to cite particular instances. The alteration of the coal-seams between Possil and Kilsyth is a good general example. Mr. David Ferguson (vol. lv., page 145) expresses the view that the qualities of the Kilsyth Main Coal are quite independent of any intrusive agency. At the Drumbreck Pit the Kilsyth quartz dolerite sill lies a few fathoms below the Index Limestone, and is thus above the coal-seams. There is no direct evidence of an underlying sill, but the presence of the overlying sill may be sufficient to account for the coking qualities of the seams. As Mr. James Hamilton remarks, the only effect of an igneous rock on a seam lying below it must be that of heat. Research-work on the lines indicated by Mr. Hamilton would be very valuable, and the suggestion should be placed before the Fuel Research Board.

On page 63 of Vol. LIV., lines 10, 18, 19, and 21, "grams" has been inadvertently printed as "grains."

DISCUSSION OF MR. STEWART CHAMBERS'S PAPER ON "THE REPAIR OF A CIRCULAR SHAFT OF SMALL DIAMETER."*

The PRESIDENT (Mr. D. M. Mowat): The ordinary way to repair a shaft that had collapsed in this way would have been to start from the bottom, but that would have exposed the workmen to serious risk from falling *débris*. In a case of arching in a pit-bottom under similar circumstances, a fall took place, 36 feet high, the arch being 26 feet wide. It was the greatest relief to all connected with the undertaking when the first ring of brickwork was got into the shaft, because until then there was no refuge-hole to go to. The operation described by Mr. Chambers appealed to me as a somewhat similar experience to the one just mentioned. If work had been started from the bottom, there would have been no escape for the men in the event of a fall of *débris*. It would not have mattered how small the piece was that fell; it would almost certainly have caused a fatal accident if it struck anyone in the course of its descent.

Mr. RICHARD KIRKBY (Wemyss): With regard to the boxes and barrels used to fill up the cavity, I wonder whether something else could not have been obtained to take their place. Probably they were the best filling that could have been used, as stones and refuse of that kind might have been too heavy to take down with ease. As there is concrete in the sides of the walls, I do not think that the boxes and barrels will give much trouble.

The PRESIDENT: I think that in an operation of this kind an arrangement should be made to make the lining tube bigger than actually required, so as to allow for want of alignment. In a sinking where the cylinder gets often out of plumb it is good practice to make it larger than is actually required, so as to get a straight line through. The paper contains many practical hints which will be of value to others faced with similar difficulties.

The further discussion of the paper was adjourned.

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., page 203.

THE ECONOMY OF BRIQUETTING SMALL COAL.

By J. A. YEADON.

Introduction.—Before entering into a full consideration of the immediate subject of the paper, it might be well to mention briefly two other important questions which are inseparably connected with it, namely, the conservation of coal and the utilization of waste materials. "Coal" in this case includes bituminous, non-bituminous, and anthracitic coal, and also coke-breeze.

Conservation of Coal.—Never before in the history of this country has this subject assumed or obtained the importance it now commands. Our industrial wealth depends very largely on an abundant supply of coal; this country is rich in its ample possession of this mineral; and it is our duty to posterity to ensure that we "conserve" this great asset by striving to secure the best results from every ton of coal brought to the surface.

Utilization of Waste Materials.—All trades and manufactures in this country are (or should be) closely interested in this question, which is bound to increase in importance in the future. It will be one of vital interest in our inevitable competition with other leading nations after the conclusion of peace. So far as fuel is concerned, we have hitherto been *one* of the most wasteful, if not *the* most wasteful, nation in the world. We allowed, and are still allowing, immense quantities of mined small coal to remain in our pits as not worth bringing to the surface. At the present time large quantities of usable small coal are lying in heaps at bank as comparatively useless and unsaleable, there to deteriorate in quality or to break out into spontaneous combustion, and thus to become a nuisance and a danger to those in the immediate neighbourhood. The small coke-breeze from coke-ovens and gas-works has also been allowed to accumulate in vast heaps as a useless material, or has been used for ballast on the railways, and great heaps of "slimes" from coal-washers are still allowed to accumulate as waste material. Every ounce of the above material could be utilized profitably, given a suitable process and proper machinery. Very much of this waste might have been avoided in recent years if more sympathetic interest and practical help had been forthcoming from coal authorities towards those who, knowing all these facts, were prepared and ready to undertake special enterprises to meet and overcome successfully the present abnormal and unprecedented deficit in our coal supplies.

Economy of Briquetting Small Coal.—The following advantages can be claimed for coal-briquettes when properly made:—

(*a*) According to Prof. Goss, the calorific power of good quality briquettes is higher than that of the coal from which they are made, when pitch is used as the agglomerant.

(*b*) Briquettes thus produced are unaffected by exposure to the weather, and suffer less deterioration than the coal itself.

(*c*) Briquettes produced from small coal can be made suitable for any purpose for which coal is ordinarily used for steam-raising or heating, the one exception being for smelting in blast-furnaces.

(*d*) Under normal conditions, and with suitable and the latest improved processes and machinery, any ordinary small coal can be converted into marketable briquettes, and leave a satisfactory profit to the makers. Good qualities command the same price per ton as large coal.

It is the exception *in this country* to find a colliery provided with a briquetting plant. Before the war, it was the exception to come across any leading Continental colliery company *not provided* with a suitable briquetting works.

Briquetting has been described as the method or process by which small coal, when mixed with a certain proportion of pitch (or other suitable agglomerant), is converted into compressed blocks of fuel called "briquettes." So far, pitch easily holds the field as the most suitable agglomerant for this purpose. It is a production from the distillation of gas-tar, or from blast-furnaces where, as in Scotland, coal is largely used for smelting. Pitch has the following important qualities: (1) it helps efficiency; (2) it adds no "ash"; and (3) the briquettes so made are weather-proof.

A number of other agglomerants have been tried, but without success. Various attempts have also been made to dispense with an agglomerant and to produce briquettes from small coal only by applying enormous pressure by means of very powerful machinery; but, so far, not one of these methods has proved a commercial success. When obtainable at a reasonable price, pitch still holds the field. At the present time there are large accumulations of pitch in this country simply waiting for a suitable process for its utilization. One of the best of these is decidedly the manufacture of coal-briquettes.

Method of Manufacture.—Briefly, the process of briquetting consists in the mixing of the small coal with a suitable proportion of pitch, these ingredients being then thoroughly ground together to the requisite fineness and subjected to the action of injected superheated steam, which softens the pitch and makes it plastic. The heated mixture is then fed or charged into the briquette press, where it is moulded, powerfully compressed, and converted into finished briquettes ready for delivery into the wagons, or for stacking on the open ground. When cold, they are as hard as coal, and are then ready for shipment or use.

The proportion of pitch required for agglomeration varies according to the nature and quality of the small coal used, ranging generally from 7 to 10 per cent. If the coal is wet, or if it contains a large proportion of ash, more pitch is required. The drier, cleaner, and more bituminous the coal, the less pitch is required.

Rectangular and " Ovoid " Forms of Briquettes.—The briquettes produced in this country are, generally speaking, of two forms or shapes, the rectangular and the " ovoid." Until very recent years, nearly the whole of these briquettes were rectangular, this being the most suitable shape for shipment, as the greatest tonnage weight per cubic yard can be stacked in the hold of the ship. The best quality of rectangular briquettes are those which are compressed from both sides, which gives a more even solidity to the briquettes, and also " rounds off " all the edges on both faces of the briquettes, thus minimizing breakage in handling. This system, first introduced by Messrs. Yeadon & Company, Leeds, over forty years ago, was soon copied, and is now adopted almost universally by the leading Continental makers of briquetting machines.

The first briquetting plant in Scotland on this system was erected thirty-two years ago for Messrs. William Baird & Company, Limited, at their Lugar Works, and their example was soon followed by a number of other leading Scotch firms. At the present time a briquetting plant on this system is working at the Polmaise Colliery, Stirling, with an output of 400 tons per day of 10 hours, nearly the whole of the production being for export. The rectangular briquettes produced in Scotland vary in weight from 3 to 14 pounds each, the larger sizes being for marine and locomotive consumption, and the smaller for domestic or manufacturing use. Briquettes intended for general shipment should contain not more than 10 per cent. of ash in the coal used; for best qualities, suitable for naval requirements, 8 per cent. is the maximum.

At Cramlington Colliery, Northumberland, a briquette plant is at work producing both rectangular and ovoid briquettes. Another similar plant is now being erected for the Manor Powis Company, near Stirling.

The ovoid form of briquette is rapidly being adopted in this country. They have been made in America and on the Continent for a number of years. They are made in different sizes, varying in weight from 1½ to 6 ounces each. They are especially suitable for house-fires or boiler consumption, and have evidently come to stay.

The great advantage of the ovoid briquettes is that the smallest sizes and the most inferior qualities of coal, even when containing as much as 20 per cent. of ash, can be utilized profitably in this manner for boiler-consumption, thus increasing the quantity of coal of larger size for sale. Coke-breeze from the gas-works and coke-ovens, "slimes" from the coal-washers, and anthracite duff can all be utilized profitably in this manner. These briquettes allow free circulation of air in the boiler-furnaces, and form no "clinkers" on the grate-bars.

At the Beckton Gas Works, London, and at the Liverpool Gas Works, plants are at work producing ovoids weighing 1½ ounces each from gas-coke breeze, agglomerated with pitch. At the Wombwell Main Colliery, Barnsley, a plant produces 1½-ounce ovoids from a mixture of coke-oven breeze, slimes from the washer, and 5 per cent. of small coal, agglomerated with pitch. In each of these cases, the ovoids command a large sale. At the Clifton Colliery, Nottingham, and at the Dinnington Main Colliery, Yorkshire, plants produce ovoid briquettes from small coal agglomerated with pitch.

Conclusion.—I cannot do better than conclude by quoting from a paper I read on this subject before the South Wales Institute of Engineers in 1917:—

> "It will be readily understood that no one fixed standard type of briquette plant will be suitable for every material. In every case the design of the plant and the process of manufacture have to be carefully considered and carried out as will be found most suitable for the materials to be utilized; but the writer makes bold to affirm, after forty years' experience, that, all other things being equal, there is no small coal or coke in this country which cannot be profitably utilized, provided the matter be put into competent and experienced hands, and that the proper and most suitable process be adopted.
>
> "After this war, it will be necessary for us to study economy and the utilization of waste materials in this country much more than we had ever done in the past. We shall not have to throw usable stuff on the muck-heap and let it take fire itself. We can utilize it all, and we can utilize it profitably. The sooner we fully realize and act upon this, the greater will be the benefit to the country we all love so well."*

The PRESIDENT (Mr. D. M. Mowat): Have you made briquettes from coke-breeze alone—that is, without any admixture of coal?

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* Coal Briquetting, with Special Reference to Anthracite Coal," by Jno. A. Yeadon, *Procs. South Wales Inst. Engineers*, 1917, vol. xxxiii., page 152.

Mr. J. A. **Yeadon** (Leeds) at this point exhibited a number of samples of briquettes, including one or two which were made from coke-breeze, and containing 8 per cent. of pitch, and said: At Wombwell Main Colliery they work on this mixture. They will not let anyone into the secret as to how they do it.

Mr. **Peter Milligan** (Gorebridge): This is a subject to which many of us have devoted a great deal of consideration, but the difficulty I have experienced is in connexion with the moisture to be found in the usual duff-coal taken from the washer. Along with that moisture there is also a considerable amount of slime, and that makes matters worse. If there was any practical method of drying the duff sufficiently, we might see our way to manufacture briquettes. We know that briquettes are a great success —even when made from this washer material—if they can be manufactured at prices that will pay.

Mr. **Yeadon**: The Manor Powis Colliery Company, Stirling, are to make their briquettes entirely from washed coal, and are putting up, in addition to the briquetting plant proper, a furnace for drying the washed coal. So long as, and provided that, the washed coal, the slimes, or whatever it may be, does not contain more than 10 per cent. of moisture, the material can be made into very satisfactory briquettes.

The **President**: More than one-half of the output of coal in Scotland in its natural state contains 10 per cent. of moisture. Most of the Coal-Measure coal contains that amount.

A **Member**: What appears very strange to me is the specific gravity of some of the samples exhibited. I cannot understand why they are so heavy; they are heavier than pieces of common coal.

Mr. **Yeadon**: Taken as a general rule, if the briquette is rectangular, the specific gravity is the same as coal.

Mr. **Richard Kirkby** (Wemyss): I do not think that we waste any coal underground. It all goes to the surface. We wash the whole of our small coal, and as we can consume all the duff we make, we arrange to make it as poor as it can be burned in the boilers. There is, therefore, nothing wasted except what goes up the chimney. In burning this duff at one colliery where the draught is particularly good, we lose a considerable proportion out of the chimney top. It comes down all round like snow, and sometimes lies to a depth of 3 or 4 inches at places. I wonder whether it would pay us to make that stuff into briquettes, or whether the briquettes in the burning would disintegrate and fly up the chimney in the same way as the duff.

Mr. Yeadon: A good deal, of course, depends on the coal—whether it will burn to coke. For instance, anthracite will not coke: it burns through to small ash. On the other hand, bituminous coal burns to coke and continues to burn away as coke. That is the difference between anthracite and bituminous coal. In South Wales there is a large accumulation of anthracite duff, and this duff is being sent out to France, where it is being made into ovoid briquettes at Bordeaux. Within the past fortnight or three weeks trucks of anthracite ovoid briquettes from South Wales have come into Leeds, the idea being to see whether the householders in that city will make use of them. I have tried some of them in my own house; they produce quite a hot fire, and what might be called an ideal arrangement so far as cleanliness goes.

Mr. G. L. Kerr: Do the briquettes burn with the ordinary chimney draught the same as with small coal in the boilers?

Mr. Yeadon: Yes.

The **President**: I do not think that Mr. Kirkby's question has been answered. If a briquette made from very fine coal is put in the fire, will it keep together in the lump, or will it fall away into small dust?

Mr. Yeadon: Coke will, usually, burn away as coke and remain in the lump.

Mr. Kirkby: Unfortunately, our coal does not coke; there are no coking properties in it at all. When you see it on the ground, it is in the form of fine coke cinders, but still it does not coke in the fire. The consequence is that the strong draught carries it up the chimney and distributes it all over the countryside.

Mr. Yeadon: When I spoke previously about "coking coal," I meant by that phrase all bituminous coal, which when made into a briquette will burn away as coke until it is entirely consumed. Under normal conditions, all things being suitable, the cost of a briquetting plant may be realized in two years at the outside out of the profits alone, and quite possibly in the first year. The most important thing is to go about the matter in the right way. You must have a distinct plant to suit the conditions from the beginning.

The further discussion of the paper was adjourned.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING ENGINEERS.

FORTY-SIXTH ANNUAL GENERAL MEETING,

HELD AT THE CENTRAL SCHOOL OF SCIENCE AND TECHNOLOGY, STOKE-ON-TRENT,
NOVEMBER 4TH, 1918.

MR. JOHN GREGORY, RETIRING-PRESIDENT, IN THE CHAIR.

SIR JOHN CADMAN was unanimously elected President for the ensuing year, and delivered the following Address:—

PRESIDENTIAL ADDRESS.

By PROF. SIR JOHN CADMAN, K.C.M.G., D.Sc., M.INST.C.E.

When I accepted the invitation of the Council to be your President for the ensuing year, I did so with no little reluctance, although, I am sure I need not tell you, with the very greatest pleasure. My hesitation in agreeing to receive the honour you have conferred upon me could be due to one cause only, and that is the strenuous work which my duties in London demand of me at the present moment—work which will, I fear, make it impossible for me to give to the Institute the time that it has the right to expect from its President.

However, I know very well that, like myself, everyone of you is occupied fully in taking his share in the great struggle in which we are all engaged, and that the work of the Institute must of necessity be secondary to the efforts we are making in the interests of our national welfare and the civilization of the world. At the present moment there is no body of men to whom our nation and its allies are more anxiously looking for assistance than those engaged in coal-mining; and although the Institute itself must inevitably " mark time " for a season, my ambition is that it may be my happy lot to be acting as your President when peace once more reigns.

To occupy the Presidential chair of the North Staffordshire Institute of Mining Engineers—an Institute of which my father was one of the original members, and who in 1898 was himself its honoured President—an Institute, moreover, in which I may almost say I have been cradled—is to me more than one of life's ordinary pleasures. It brings back recollections that will remain with me so long as memory lasts; and, in acknowledging gratefully the confidence you have placed in me, I can only assure you that I will endeavour to emulate to the best of my ability the noble example of those who have preceded me.

But I must confess that in the present circumstances I feel it no easy task to address you, and I must crave your indulgence with me in the few brief, and I fear somewhat disjointed, remarks that I am about to make concerning the grave situation with which the coal-mining industry is confronted to-day, and some of the problems which the mining industry is destined to face in the future.

At the present moment there is a world-shortage of coal—a shortage which must of necessity affect very seriously the achievement of the plans of our fighting services, which may possibly even delay the attainment of that victory, decisive and complete, which the allied nations are determined to secure, and at the same time may complicate the difficult negotiations consequent upon the cessation of hostilities.

I feel bound to say that it is not sufficiently recognized what this shortage of coal means to the allied cause. In order to ensure supremacy on the field of battle, to guarantee the results of victory so dearly won, the civil, military, and naval organizations of the allied nations must be maintained in a state of efficiency superior to those of the enemy. The power which is necessary to move the great allied machine must be maintained at its very maximum: materials and weapons of war must be turned out in ever-increasing quantities; civilians who are engaged in national work must be warmed and fed; troops must be transported and properly and efficiently cared for; and the million and one details on which the successful operations of a nation at war so largely depend must be carried out at all costs with maximum speed and efficiency. In this colossal task I have no hesitation in saying that the provision of adequate supplies of coal and oil is of greater importance than the supply of any other commodity of war, or the calm of peace which follows war. Although peace seems within reach, we cannot afford to run any risks, and our greatest effort was never more necessary than to-day.

It is too late now, nor can it serve any useful purpose, to denounce or protest against the circumstances that have been instrumental in creating the present difficulty. Furthermore, it is clear that if men had not gone from the mines a very perilous military position would have been created. We are face to face with a critical situation which has to be remedied, and mining engineers and leaders of the mining industry have to put their shoulders to the wheel to find a remedy and avert a disaster. I need not tell you that it is incumbent upon you to lead and stimulate those employed under you and to battle against odds which appear almost insurmountable. It is you, gentlemen, as officers in the civilian "firing-line" at home, who have to lead the country to victory, and victory is being and will be secured in the coal-mines of England just as effectively as on the battlefields.

Never before these awful days have we understood what selfishness really means. Prussian greed and cupidity have brought home to everyone of us in some way or other the horror of this terrible war, and I feel it my duty as your President to utter a word of warning, and remind you that we have in this country another struggle before us so long as industry sacrifices output in confronting problems of wages, absenteeism, profiteering, and all those misfortunes—nay, vices—of war, which must, if not arrested in time, inevitably lead a nation to destruction. I am one of those who believe that British democracy is capable of, and prepared to make, endless self-sacrifice when appealed to properly and intelligently, and I know of no body of leaders of industry or working men who are more equal or better fitted to meet any and every emergency than those engaged in mining, and, I will add, especially those who are working in the coalfields of North Staffordshire.

One has only to be present at a mine after a colliery explosion to realize what grit and determination exist in all ranks of the mining industry, and to learn that in an emergency such a word as "selfishness" is unknown in the mining vocabulary.

Let me remind you that we are faced with an emergency to-day which is greater than any that has ever confronted us. I need not enlarge upon it, for you know the critical position we are in far better than I can tell you. It is our duty to ask ourselves the question: "How is this state of affairs to be met?" The real remedy can only be found by lifting the barrage and laying bare the truth—that coal is as vital and as essential a war commodity as men and rifles, and well-nigh as precious; in fact, coal may almost be looked upon as equivalent to human flesh and blood. By providing an abundance of coal, we can hurry forward the victory and save the lives of thousands of those splendid men who are fighting for us, and can permanently reap the fruits of victory which have been so dearly won. From the mine-manager to the pony-driver the country requires an almost superhuman effort this winter if the war is to be brought to a complete and satisfactory conclusion, and not drawn out with ever-increasing loss of human life. It is the duty of every man connected with a coal-mine to-day to do his level best to increase the output, and strive his hardest to maintain that increase, however great his personal sacrifice may be.

I want to say a few words regarding one or two of the problems which the not far distant future will have to solve.

A great deal of attention is being paid at the present time to the subject of reconstruction, as well as to the necessity of a complete reorganization of our methods of conservation of coal; so I am sure you will not consider it out of place if I refer briefly to the direction in which this problem is developing. It may be stated very simply that the main objects which must be aimed at are these:—

(1) To secure the greatest quantity of coal from a given seam with the minimum expenditure of labour and capital; and

(2) To ensure that the maximum energy and value shall be extracted from every ton of coal that is produced.

There are at present two bodies which are giving their time and attention to these important questions, and some excellent preliminary work has already been done. These two bodies, to which the country is already very much indebted, are the Coal Conservation Committee of the Ministry of Reconstruction and the Department of Fuel Research, which is working under the Committee of the Privy Council for Scientific and Industrial Research.

The Coal Conservation Committee has indicated in its *Final Report** (which ought to be carefully studied by everyone connected with mining or the allied industries) the general lines upon which development should proceed, while the Department of Fuel Research, under the guidance of its Director, Sir George Beilby, has established a very definite policy of research, which, if carried out vigorously, cannot fail to lay the foundation of a much more scientific and enlightened use of fuels.

The Coal Conservation Committee has directed its attention especially to the following matters:—

(1) Improvements in mining methods to prevent loss of coal and to minimize cost of production.

(2) Improvements in methods of using coal for power, light, and heat, and the recovery of bye-products.

(3) The steps to be taken in order to secure the development and extension of existing coalfields.

At present there are no fewer than a dozen government departments and sub-departments which are connected with mining in one way or another, and the Conservation Committee has suggested that a Ministry of Mines should be created which should co-ordinate these different departments and the mining interests of the whole country.

The Committee recommends also that the coal consumed in collieries should be specially considered in conjunction with the problem of economy in the use of coal for power purposes, and that coal at present left underground should be utilized by the stimulation of outlets for this class of fuel.

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* 1918 [Cd. 9084], price 1s.

They advise also that seams of abnormal thickness should receive special investigation, so as to prevent the great wastage which the present method of working involves.

It is suggested that more systematic methods should be introduced when pillar-work is used; that barriers should be left only for economic purposes, and not according to the caprice of legal fanatics; and that central drainage schemes should be introduced in order to pump the water more efficiently from recognized coal-basins. They further advocate that the more enlightened methods of coal-working which are in vogue in certain of our collieries should be introduced into all collieries throughout the country, and that the important problem of relative order of working seams of coal should be governed by principles which will entail the minimum permanent loss of coal.

The Committee strongly advise the establishment of machinery whereby fractious surface owners may be prevented from harassing the scientific and economic development of mineral fields, and that facilities should be introduced to enable the working of coal-mines to be carried on without exorbitant charges being levied for royalties and wayleaves.

They also insist that the following principle should be recognized as one on which the success and welfare of workmen as well as employers depend—that it is only by increasing production per head of persons employed that the British trade position can be maintained.

The use of labour-saving devices of various kinds is also strongly advocated, while other recommendations are that a general policy should be followed of increasing as much as possible the technical education of all those employed in the industry; that the expenditure of local authorities, which has tended to increase the cost of production in the industries of the country, should be confined within the limits of strict economy; and, lastly, that settlements of disputes should be handled by machinery which will prevent the possibility of strikes and lock-outs.

These are some of the principal recommendations of the Committee to which I have referred. The same body has also been giving its attention to the question of improvements in methods of using coal, and in this direction they have further recommendations to make. The more important ones I will indicate very briefly. They strongly advise that a more economic distribution of power should be devised in Great Britain, and that the present inefficient system whereby six hundred districts are supplied by electric power should be curtailed to something like sixteen areas only.

They consider it essential also that there should be established large super-power plants capable of supplying through comprehensive distributive systems the needs of the community at the lowest possible price, and that machinery should be established whereby these great plants will be able to feed all the industrial centres of the country.

It is estimated that the introduction of such a scheme would result in an annual saving of 55,000,000 tons of coal at present employed in the manufacturing industries.

The Committee further considers it necessary that attention should be given to the more efficient treatment of coal, with a view to utilizing more effectively those which are at present consumed in a raw state, making use of products which are at present unsaleable, and extracting essential materials, such as motor-spirit, fuel, oils, and materials that are used for the preparation of explosives, dyes, and drugs.

They also very strongly advocate that the gas and coke industries should be specially considered, with a view to their general development in relation to existing operations and those traversed by the reorganization of the power, light, and heat systems which will follow the development proposed.

Another important matter to which attention has been given is the question as to what steps are to be taken to secure the development and extension of existing coalfields.

It is very well known that there are large areas overspread by geological formations newer than the Coal-Measures, of which the character of the underlying Palæozoic rocks is wholly unknown, and it is recommended that comprehensive surveys should be undertaken and boreholes put down to test the value of these areas.

The Fuel Research Department have laid down a definite policy for a most thorough and systematic examination of all classes of fuels, and they have reported their intention of investigating the treatment of fuels, with a view to the extraction of economic commodities which, when carried to a successful issue, can only result in stimulating coal-mining activity in this country.

I have summarized briefly the main lines on which this great problem is being opened up, and I commend the reports of the Coal Conservation Committee and of the Fuel Research Board to all who have the interest of coal-mining at heart. The work that these bodies have done already indicates that the policy is being prepared from which will surely emerge conditions and developments which should add very greatly to the prosperity of the whole mining industry.

All these problems have from time to time been the subject of individual enquiry, and this Institute has played no small part in the attempt which has been made to focus investigation on some part or other of the development of the great mining industry.

We are now being forced to consider problems from a very different point of view, and the scientific work which the Institute in future will be called upon to perform—to use a military metaphor—is as " an army working under a single and supreme command." A plan will be laid down which will be in the interests of the nation as a whole, and we shall be called up to fill in a corner which will assist in developing, may I say, the Imperial picture. We have got to watch and see that individual enterprise is not stifled, but directed or unconsciously led to support the Union Jack. Never again must the results of British effort be thrown to the German machine to mould into weapons for our destruction. From the coal of Britain the wealth of this Empire is still largely to be drawn, and on the work of such Institutions as this much must inevitably depend.

I should like before I conclude to add a word regarding the present political and military situation. I have just returned from a visit to Italy and France, and have had the opportunity of discussing the allied position with some of our leading military men. The feeling everywhere expressed is that the allies must not—nay, dare not—stay their hand until this war is thoroughly and completely won. They are prepared, with the splendid men under their command, to do their utmost to secure the victory for which we strive, and on all sides the hope was expressed that there should be no doubt that the people at home are behind them in the same wholehearted spirit.

I know only too well the feeling of North Staffordshire, which has at the front some of the finest men that our army contains. It is those lads, and their comrades in France, whom we are counting on to carry us to victory. But let me add, gentlemen, that we have not only to win this war out and out—we have also something else to win, and that is peace. And in this we at home have the biggest part to play. I cannot venture to predict how far or how near that peace is still from us, and I fear it is not quite so near as many have come to imagine.

I do not pretend to know what the final peace terms of the allied powers may be; but I will venture to say I do not think a satisfactory and honourable peace can be attained unless it be preceded by an absolute, complete, and unconditional surrender on the part of the military autocracy of Prussia.

We feel ourselves that the military forces of Germany are beaten. Day after day they are being driven back nearer to the Rhine by the British, French, and American troops; but it may still require some stiff fighting before we can convince the

German people themselves that the game is up, and that their dream of military domination of the world has passed for ever. What we at home have to do is to keep our shoulders to the wheel, and strain every nerve in order to strengthen and assist in every possible way our valiant troops in France.

Not only do our sons and brothers who are fighting for us need all the assistance the nation can give them during the coming weeks and months, but also those who are responsible for securing the fruits of victory, the peace of the world.

If we pay any attention to the tears and whining of the German people and Government, we shall run the risk of being cheated of that victory for which so many have made the supreme sacrifice.

The German nation has been brought up in a tradition of duplicity; my own impression is that their proposals for peace are altogether hollow and insincere, and have been put forward in the belief that, if they can only get people to talk of peace, they will be all the less inclined to fight.

Gentlemen, we dare not place any reliance on these vague and camouflaged utterances. Until there are signs of a change of heart and spirit in the German nation, the only thing for us to do is to fight and work on resolutely until we have driven it home to Germany that their creed of force and brutality does not pay, and that deliberate militarism is an offence against humanity.

If Germany should escape retribution for the crimes and brutality of which she has been guilty, she will remain as lost to shame and as dead to honour as ever, and this appalling war will have been waged in vain.

Let me, then, gentlemen, beg to you to throw yourselves heart and soul with renewed vigour into the struggle for a further brief period, and here in the mines of Staffordshire you will be able to claim a very real share in the reconstitution of the liberty and happiness of the whole world.

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ANNUAL GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
OCTOBER 8TH, 1918.

MR. WILLIAM PICKUP, F.G.S., RETIRING-PRESIDENT, IN THE CHAIR.

Mr. A. J. A. Orchard was unanimously elected President for the ensuing year.

THE RELATION BETWEEN THE CALORIFIC VALUES AND THE ASH-YIELDS OF COAL-SAMPLES FROM THE SAME SEAM.

BY THOMAS JAMES DRAKELEY, M.Sc. (LONDON), A.I.C., F.C.S.

In a former research on coal-washing* a number of calorific-value estimations were made. At any one of the coal-washing plants visited in connexion with the above research a sample of raw coal, samples of each class of washed coal, and a sample of the slime were collected. These samples, therefore, may be assumed to have formed a series of mixtures of the same pure coal with varying quantities of impurities. As the calorific value and the ash-content of each sample were determined, an admirable opportunity was offered for studying the influence of the impurities on the calorific value.

At that time it was noted (*loc. cit.*, page 442) that for each set of samples from a washer the calorific value was almost proportional to the quantity of ash-free material in the coal. That is—

$$\frac{\text{Calorific value} \times 100}{100 - \text{Percentage of ash}} = \text{Constant.}$$

This statement obviously conveys the idea that zero calorific value is only reached when the percentage of ash in the sample becomes 100. When, however, the calorific values and the corresponding ash-contents were plotted (Fig. 1, Plate I.), it was evident that the above equation was only an approximation. It was observed that the points lay fairly evenly in a straight band across the diagram, and that if an average straight line were drawn amongst the points, it cut the horizontal axis at 88·9 instead of at the 100 point. This indicated that zero calorific value was associated with an average ash-content of about 89 per cent., and hence a correction in the approximate conclusion drawn in the previous paper was necessary. Incidentally, it may be mentioned that the above equation is claimed very frequently to be entirely satisfactory for calculating, from one calorific value of a coal, the calorific values of other samples of the same kind of coal. Recently, a similar equation appeared in the standard technical methods compiled by the Chemists' Committee of the United States Steel Corporation (*Colliery Guardian*, 1918, Vol. CXVI., pages 547-548).

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* "Coal-washing: a Scientific Study," by T. J. Drakeley, *Trans. Inst. M.E.*, 1917-1918, vol. liv., page 418.

The chief impurity in the raw coal is shale, and its presence reduces the calorific value of the coal-sample, and at the same time increases the yield of ash. The shale—as distinct from carbonaceous shale—is a material which is incombustible, and therefore possesses zero calorific value. Hence, as the quantity of shale in the sample increases the calorific value decreases, until it reaches zero for a sample of pure shale. The percentage of ash obtained by igniting shale never reaches 100 per cent., although the value approximates to that number. It is therefore to be concluded that any line drawn to show the relation between the calorific value and the ash-content should cut the horizontal axis at a point representing the percentage of ash yielded by the sample of shale.

In order to render the results mentioned in the previous paper more complete, it was necessary to determine, if possible, the ash obtained by igniting samples of shale from each of the washing plants. The samples of shale were carefully selected so as to exclude any carbonaceous matter, and therefore could be assumed to possess zero calorific value.

The results of the estimations of the percentages of ash in the shale samples are included in Table I., which also gives the calorific value and ash estimations made in connexion with the recent research on coal-washing, together with many determinations not included in the paper on that subject. The values given in Table I. are plotted in Fig. 1 (Plate I.) It may be observed that the average ash-content which gives zero calorific value is 88·4 per cent., whereas the average line cuts the horizontal axis at 88·9 per cent.

TABLE I.—CALORIFIC VALUES AND ASH-CONTENTS OF COAL-SAMPLES.

Reference No.	Ash. Per Cent.	Calorific value. B.T U.
1	2·61	14,404
	3·91	14,128
	3·93	14,114
	6·11	13,639
	11·63	13,034
	22·20	11,366
	80·02	0
2	3·51	14,366
	6·61	13,883
	6·93	13,858
	7·18	13,822
	8·35	13,775
	9·62	13,231
	21·72	11,448
	28·33	10,294
	90·17	0
3	3·92	13,689
	8·89	12,902
	13·55	12,422
	14·16	12,352
	23·90	11,181
	24·02	11,160
	90·88	0
4	3·28	14,116
	8·65	13,214
	8·66	13,190
	9·75	13,019
	15·73	11,983
	25·04	10,356
	91·96	0
5	3·27	14,107
	8·64	13,433
	8·73	13,396
	11·32	12,794
	15·39	12,094
	26·49	10,188
	91·05	0
6	4·35	13,883
	8·58	13,299
	8·97	13,234
	10·90	12,935
	17·37	11,695
	26·35	10,306
	89·42	0
7	4·63	14,170
	10·07	13,397
	18·03	12,004
	31·22	9,922
	90·45	0
8	5·01	14,236
	7·53	13,853
	9·21	13,622
	14·23	12,739
	16·51	12,141
	28·37	10,387
	90·47	0
9	4·13	13,928
	11·46	12,832
	16·74	12,008
	20·06	11,500
	86·61	0
10	4·36	14,042
	7·19	13,565
	7·70	13,478
	10·49	13,052
	12·48	12,490
	23·36	10,807
	88·82	0
11	3·35	13,826
	8·86	13,023
	17·67	11,606
	34·36	8,947
	87·47	0
12	2·63	14,386
	4·73	14,042
	9·13	13,252
	15·99	12,209
	89·12	0
13	3·12	14.373
	4·47	14,225
	11·35	12,910
	13·71	12,708
	26·36	10,495
	86·54	0
14	3·64	14,008
	9·93	13,057
	19·98	11,576
	45·73	7,512
	81·14	0
15	3·47	13,934
	7·87	13,291
	8·03	13,246
	10·76	12,909
	19·62	11,444
	25·71	10,361
	91·38	0

This difference, which is really unusually small, may be accounted for in several ways. First, an equal number of points were not plotted for each of the fifteen coals, and the preponderance is in favour of those giving a high ash-content for zero calorific value. Indeed, if, in determining the average, allowance be made for the number of points plotted for each sample, the value of the ash-content corresponding to zero calorific value is 88·6 per cent. Secondly, as pointed out previously (*Trans. Inst. M.E.*, 1917-1918, vol. LIV., pages 441 and 451), the determinations of the calorific values, in connexion with that paper, were not carried out as accurately as the author would have desired. The calorific values were sufficiently accurate for the purposes of the research then in hand, and the results, with the addition of the other values, have proved of great importance, as indicating that the probable relation between the calorific value and the ash-content may be represented by a straight-line graph.

It must not be concluded that a more accurate method of determining the calorific values would have resulted in all the points arranging themselves on the average line shown in Fig. 1 (Plate I.). Such an effect would most certainly not have been produced. On the other hand, there seems to be no doubt that more reliable results would have indicated that the points for each set of samples were on a separate straight line.

Parr (*Illinois State Geological Survey*, 1909, Bulletin No. 16, page 212; 1914, Bulletin No. 29, page 40) has shown that, after allowances have been made for such impurities as ash and moisture, the calorific value is remarkably constant for samples of coal from a particular seam over a considerable area. Therefore, for each seam of coal there is a definite line on the diagram from which the calorific value may be read when the ash-content is known. This, however, is only feasible so long as precautions are taken to avoid any errors being introduced by the presence of moisture in varying quantities.

In order to prove that the relation between the calorific value and the ash-content of a coal could be represented by a straight-line graph, the following experiments were made:—A large sample of coal was crushed so as to pass through a sieve of a mesh of 120 to the inch, and was mixed thoroughly. The powder was air-dried in the chemical laboratory of the Wigan and District Mining and Technical College. The temperature in the laboratory is maintained fairly evenly at 60° Fahr., whilst the hygrometric state of the atmosphere is moderately constant (relative humidity = 60-70 per cent.). In this way, the influence on the calorific value of the varying quantities of moisture in the samples was to a considerable extent eliminated.

This was an important detail of the experiments, as it was found that, unless particular care was taken in regard to the air-drying of the coal, the results failed to show uniformity. This is due to the fact that the presence of moisture not only reduces the calorific value, but at the same time reduces the percentage of ash yielded by the coal.

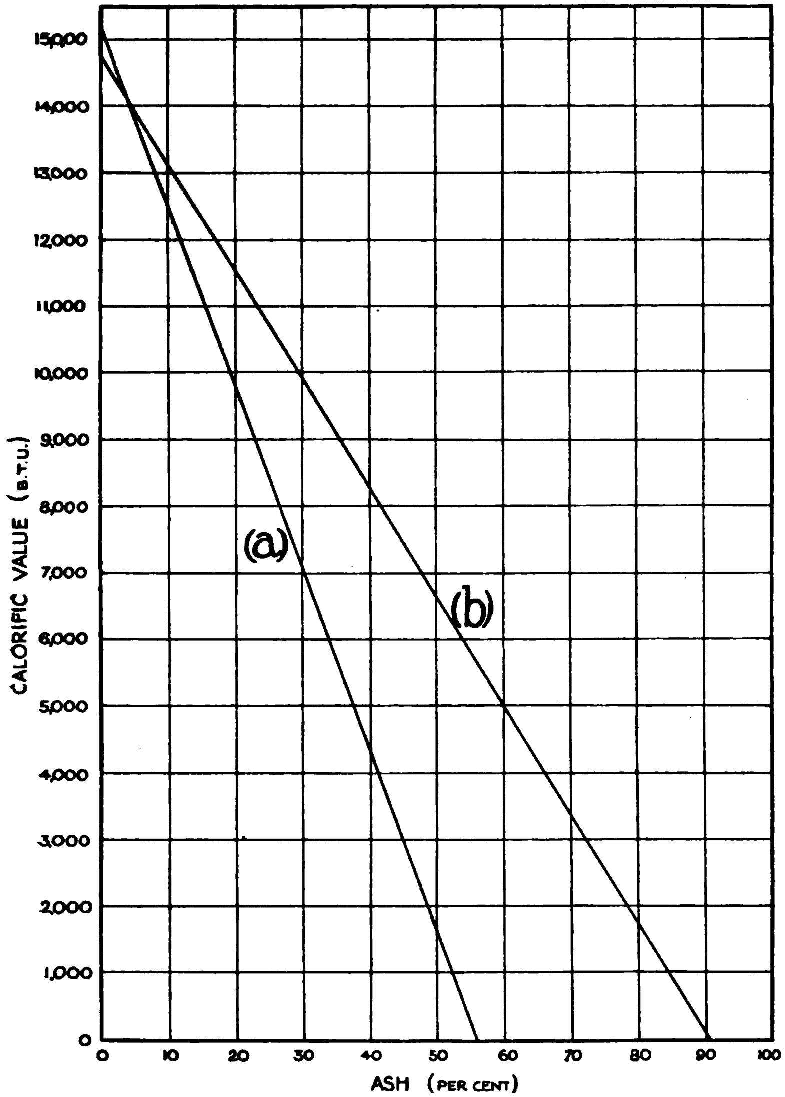


FIG. 2.—PLOTTED CALORIFIC VALUES AND ASH-YIELDS OF MIXTURES OF COAL WITH (*a*) CALCIUM CARBONATE AND (*b*) SHALE.

After the powdered coal had been air-dried satisfactorily, portions of it were mixed with different quantities of impurity, so as to obtain samples yielding different percentages of ash.

The two typical incombustible impurities which accompany the coal to the surface are calcite (calcium carbonate) and shale.

Two sets of experiments have therefore been made. In the first, mixtures of coal and pure calcium carbonate were used, and in the second, mixtures of coal and shale-dust.

The calorific value of each sample was determined by means of the Mahler-Cook bomb-calorimeter, and precautions were taken to ensure the utmost accuracy. In order to effect the complete combustion of those mixtures containing only small quantities of coal, sufficient pure naphthalene (calorific value, 17,415 British thermal units) was admixed to give approximately the same rise in temperature as with the coal-sample. The heat from the combustion of the naphthalene was deducted afterwards from the total heat of combustion of such samples. A radiation correction, calculated from a graph of the temperature readings taken at equal intervals of time, was made for each determination. The percentage of ash obtained from each sample was determined by incineration in an open muffle-furnace.

The results of the first series of experiments made on mixtures of coal and calcium carbonate are recorded in Table II., and are represented diagrammatically as line (*a*) in Fig. 2 in the text.

TABLE II.—THE CALORIFIC VALUES AND ASH-YIELDS OF MIXTURES OF COAL WITH CALCIUM CARBONATE.

Sample No.	Ash. Per cent.	Calorific Value B.T.U.
1	3·38	14,191
2	13·89	11,346
3	24·44	8,520
4	34·95	5,675
5	45·46	2,821
6	56·00	0

From Fig. 2 it is seen that zero calorific value corresponds with an ash-yield of 56 per cent. If, however, the question of heat alone be considered, it is obvious that theoretically zero calorific value should be reached when the heat evolved by the combustion of the coal is only just sufficient to decompose the calcium carbonate to form lime.

It may be shown that such a mixture of calcium carbonate with the particular coal used in these experiments would contain approximately 95 per cent. of calcium carbonate, 5 per cent. of coal, and would yield 53 per cent. of ash. It would therefore appear that the line, representing the calorific values and ash-yields of mixtures of coal and calcium carbonate, should cut the "ash" axis at 53 instead of at 56 per cent. The fact that the line cuts the axis at the 56 point indicates that, in the bomb-calorimeter, decomposition of the calcium carbonate has been prevented.

Since, therefore, the ash left in the bomb at the conclusion of a calorific value estimation is calcium carbonate, whereas the ash obtained by incineration is calcium oxide (lime), the determined calorific value of the mixture is higher than it should be by the amount of heat necessary to decompose the calcium carbonate to oxide.

On account of the high temperature of the combustion—sufficient to melt platinum wire (melting-point, 3,180° Fahr.)—it was thought that evidence of some decomposition of the calcium carbonate would be forthcoming. Actually the calcium carbonate appeared to sinter into a rather non-coherent mass, possibly with partial decomposition (compare Boeke, *Zeitsch. anorg. Chem.*, 1906, vol. l., 247). But, while the mass cooled, no doubt any resulting lime re-absorbed carbon dioxide to give almost completely the full quantity of calcium carbonate with evolution of the same amount of heat which had been necessary to bring about the decomposition. A consideration of the partial pressure of the carbon dioxide within the bomb at the conclusion of each experiment also provides evidence to account for the non-decomposition of the calcium carbonate.

It may be shown that the partial pressure of the carbon dioxide amounts to about three atmospheres, and at that pressure the temperature necessary to commence the decomposition of the carbonate would be exceptionally high. For a partial pressure of one atmosphere the temperature must be 1,517° Fahr. (Le Chatelier, *Compt. Rend.*, 1886, vol. cii., page 1,234). Hence since the final temperature of the bomb is only about 7° Fahr. above room temperature, no decomposition of the calcium carbonate will occur in the calorific-value estimations.

The bomb-calorimeter therefore gives slightly high results for the calorific values of mixtures of coal and calcium carbonate, the excess being due to the fact that the calcium carbonate is not decomposed as it would be in ordinary practice.

When calcium carbonate is thrown upon an ordinary hot household fire, it commences to decompose as soon as its temperature exceeds 1,022° Fahr. During this decomposition some of the available heat from the coal is absorbed, and as the draught sweeps the gaseous products away, the reaction proceeds almost quantitatively to form calcium oxide (lime). When the ashes fall from the grate, they are cooled, and the calcium oxide tends to reunite with any carbon dioxide with which it may come into contact. It was found, after such an experiment, that there remained over 80 per cent. of lime in the ashes.

Experiments were then made with the Lewis-Thomson, William Thomson, and Simplex calorimeters, in which the combustion takes place at almost atmospheric pressure. The instruments, however, do not admit of sufficient accuracy to register such small quantities of heat as that necessary to decompose the calcium carbonate in the mixtures. In some cases there is an initial error, due to the escape of uncooled gases and loss of heat by radiation, which necessitates an allowance of at least 10 per cent. In the use of the bomb-calorimeter, however, the experimental errors may be reduced to about 0·25 per cent.

A second set of experiments was made, using mixtures of the same coal with varying proportions of shale-dust. The results are given in Table III., and are represented by graph (*b*) on Fig. 2 in the text.

Table III.—The Calorific Values and Ash-contents of Mixtures of Coal and Shale.

Sample No.	Ash Per cent.	Calorific Value. B.T.U
1	3·38	14,191
7	29·53	9,952
8	46·95	7,098
9	64·38	4,270
10	68·71	3,542
11	90·50	0

As the percentage of ash yielded by the shale-dust is very high, little decomposition may be assumed to have occurred. It is possible, therefore, to neglect the small quantity of heat, which is lost in all probability in the chemical reaction. Hence such a graph as line (*b*) on Fig. 2, drawn through points determined by the bomb-calorimeter estimations, may be taken to represent truly the relation between the calorific value and the ash-content of samples of coal from the same seam which contain varying proportions of shale.

From Fig. 2 it is concluded that the relation between the calorific value and the percentage of ash for the same coal may be expressed graphically as a straight line, whether the ash results from the ignition of calcite or of shale.

In the purchase of coal according to a specification, it is usual to correct the price for variations in the calorific value and in the ash and moisture contents. From the above it might be argued that the " ash-content " adjustment of the price is unnecessary, as it incidentally forms the basis of the " calorific-value " correction.

In boiler practice, however, it is found that the increase in the evaporation which is observed with a cleaner sample of the same coal is not directly proportional to the decrease in the amount of inert matter in the coal. The evaporative power exceeds the expected value because the fireman can use the cleaner fuel to greater advantage. Hence the correction of the price for variations in the percentage of ash as well as the calorific value is essential where coal is purchased for industrial purposes on a specification basis.

Construction of the Diagram.—As the graph representing the relation between the calorific value and the percentage of ash of samples of coal from the same seam is a straight line, the diagram admits of easy construction. Two points, widely separated on the diagram, may be readily determined in order to fix the position of the line. First, the percentage of ash yielded by the impurity may be estimated by incinerating several carefully sampled quantities of the impurity which have been selected so as to exclude all carbonaceous matter. The result giving the maximum ash-content is accepted as that of the impurity which is free from carbonaceous matter and, therefore, possesses zero calorific value. Suppose this value to be S per cent. One point through which the line passes is obtained by marking off a distance along OX to represent S per cent. Let the point be L (Fig. 3). The second point may be determined by making, say, three estimations of the calorific value of a carefully-chosen sample of coal from the seam. Since, in skilled hands, the bomb-calorimeter will give very accurate results, the mean of the three readings may be assumed to be correct. Suppose the sample of coal has a calorific value H

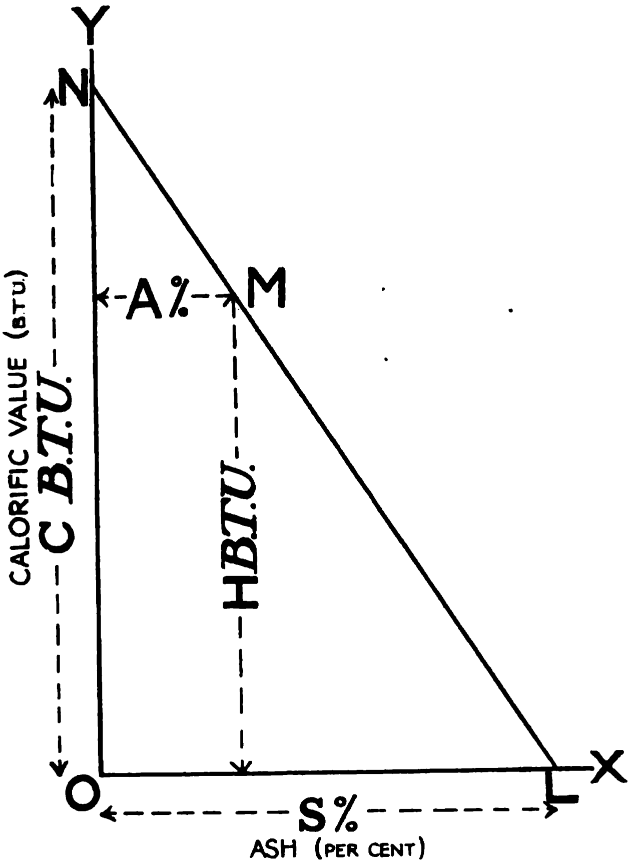


Fig. 3.—Graph showing the Relation between the Calorific Value and the Ash-percentage of Coal from the same Seam.

British thermal units, and an ash-content A per cent. The point M is plotted to represent the above values, and the line is drawn from L through M. Let it cut the vertical axis OY at N where the distance ON represents C British thermal units.

That indicates that the calorific value of the coal entirely free from ash is C British thermal units, and this value is a constant factor for the seam. An assumption, however, is made that the inherent ash-yielding material normally present in the coal is the same as the accidental impurities in the coal. In so far as the mud deposited with the coal-substance is often the same as the local impurity bands, this is true. The assumption is not, however, precisely correct; but as the error is very small, and only of scientific interest, the extension of the line to cut the OY axis at N is justified for all practical purposes.

If Fig. 2 is referred to, it will be observed that, for the same coal, there are two possible values of C, according as the normal ash of the coal is assumed to be calcium carbonate or shale. Doubtless the value 14,742 British thermal units, based upon the latter assumption, is likely to be a nearer approach to the truth than the other result 15,100 British thermal units.

Such a diagram is extremely convenient for reading off, at a moment's notice, any required values. As a rule, the ash-contents of the samples rarely exceed 25 per cent., so that there is no need to construct the whole diagram. The part giving the ash-contents up to 25 per cent. and the corresponding calorific values is all that is required, and such a diagram may be constructed on an area sixteen times that possible for the complete graph. This will allow any required values to be read off with greater accuracy. Such a diagram may be plotted most conveniently by using the equation given below:—

Mathematical.—The equation of the line LN is $y = C\left(1 - \frac{x}{S}\right)$, where y is the required calorific value of a sample of coal yielding x per cent. of ash, and C and S have the meanings respectively assigned to them above.

Calculation of the Value of the Factor C.—The value of C cannot be determined by direct experiment, as the coal always yields a certain amount of ash. It can be obtained by drawing a graph as explained in the preceding sections; but even then it is only possible to read off the value of C in an approximate manner, unless the diagram is constructed on a very large scale. The value of C may, however, be calculated from an actual calorific value determination.

Thus, suppose the selected representative sample from the coal-seam has a calorific value of H British thermal units, and yields A per cent. of ash. Then since S parts of ash result from 100 parts of impurity, $\frac{A}{100}$ parts of ash are yielded by $\frac{A}{S}$ parts of impurity. Hence in unit weight of the coal sample $\frac{A}{S}$ is incombustible. Therefore, the mineral-free coal in the sample is $\left(1-\frac{A}{S}\right)$, and this weight of coal-substance produces H British thermal units on combustion.

Therefore, the calorific value of the ash-free coal (that is, C) is $\frac{H}{1-\frac{A}{S}}$ British thermal units. Hence the calorific value of any sample of coal from the same seam may be calculated without reference to a graph.

Conclusions.—(1) For samples of coal from the same seam, the relation between the calorific value and the ash-content may be represented graphically by a straight line which does not usually cut the "ash" axis at 100 per cent.

(2) The relation may be expressed in the form of an equation such as—

$$y = C\left(1-\frac{x}{S}\right), \text{ where—}$$

C = a constant factor for the seam, and stands for the calorific value of the mineral-free coal.

S = percentage of ash yielded by the impurity which usually accompanies the coal in the mined samples.

y = required calorific value of a sample.

x = percentage of ash yielded by that sample.

(3) The value of the factor C may be read off from a graph, or may be calculated from a determination of the calorific value and ash-content for one sample from the seam by means of the equation $C = \frac{H}{1-\frac{A}{S}}$, where—

H = calorific value determined for one particular sample,

A = percentage of ash yielded by that same sample, and

C and S respectively have the same significance as stated above.

(4) In bomb-calorimeter estimations of the calorific values of samples of coal containing calcite, the temperature of the combustion may be sufficiently high to sinter the calcite into a rather non-coherent mass.

(5) The partial pressure of the carbon dioxide within the bomb, however, is high enough to prevent any final decomposition of the calcite.

(6) In consequence of the non-decomposition of the calcite in the bomb-calorimeter, the calorific value of such coal-samples will be slightly in excess of the true value. The error is so small that it may be neglected. Where shale is the chief impurity, in all probability the error is less than with calcite.

(7) Despite this restriction in the use of instruments of the bomb type, it is concluded from numerous experiments that they are the only calorimeters which give reliable results.

(8) It is essential that, for the results to conform to the above relation, the utmost care must be taken in air-drying the samples before determining their respective calorific values and ash-contents.

Mr. W. **BOLTON SHAW** (Manchester): It seems to me that Mr. Drakeley's formulæ as a whole are based on the proposition that the shale from a given seam produces the same percentage of ash no matter from where it is taken. Has he found that to be the case by experience? If the ash varies to any extent, it must upset the accuracy of the formulæ.

Mr. T. J. **DRAKELEY** (Wigan): The shale may vary in its ash-content in the same seam. The way to get over that difficulty is to sample the shale as you would sample the coal—that is, take a fair average of the shale that is likely to come to the surface with the mined coal. In the actual values that are determined for ash in shale there are eleven within the range 87-92 per cent. The shales are from different parts of Lancashire, with two or three from Cheshire, and they all give about the same quantity of ash. Shale itself has a fairly constant ash—about 89 per cent. If the ash-content varies considerably from this value, I am rather inclined to think that the shale contains small quantities of carbonaceous matter that burns away.

Mr. S. C. **LAWS** (Wigan): Supposing there were a 5-per-cent. variation, as suggested, what difference would that make when you approach that part of the diagram which relates to actual coals?

Mr. **DRAKELEY**: These shales are natural bodies, and do not possess a uniform composition, so that one would expect some variation in the values for the ash-yields. I consider they are peculiarly constant when one finds that shales from various parts of Lancashire and Cheshire show a variation of only 5 per cent. The ash got on igniting shale is generally regarded as inorganic matter, which is left behind after the moisture has been driven off. Possibly, some of these shales may have contained some chalky matter, and then, of course, they would give off a comparatively large quantity of carbon dioxide and so reduce the percentage of ash.

Mr. **Laws**: My point is simply this. If you draw your line from your fixed point *M* (Fig. 3) first, say, to the 85-per-cent. ash-content and then to the 90-per-cent. point, in the practical region for coal of 5 to 10 cent. ash, the difference in calorific value between the one line and the other will be extremely small. This difference would probably not amount to more than 1 per cent., which is well within the range of experimental error.

Mr. **Drakeley**: That is so. Even if you do get a 5-per-cent. range, the actual line will be only very slightly displaced from the original line. Up to 25 or 50 per cent. of ash—you are not likely to get coal yielding above 50 per cent. of ash—the line will approximate very closely to the present line. On the other hand, it is not at all likely that a 5-per-cent. error will occur in determining the ash-content. The value for the ash-content of the shale will definitely fix the point *L* (Fig. 3), and so the position of the line.

Mr. H. O. **Dixon** (Bolton): How would you proceed when it is impossible to secure a sample of shale free from carbonaceous matter? The seam itself might be fairly clean to look at, but burn with a percentage of ash which was not originally discernable in the coal itself.

Mr. **Drakeley**: That means that you cannot determine experimentally the point *L* (Fig. 3) at which the line cuts the axis. However, you can determine, say, three different values and thus obtain three points on the line. You could then draw the line through the points and produce it to cut the axis. The value *S* represented by the length *OL* (Fig. 3) could then be used in the formula.

Mr. J. **Drummond Paton** (Manchester): Probably Mr. Drakeley might obtain from his data on heat-absorption in ash a useful corroboration of the amount of heat dissipated in the ash-pit of the boiler. It must have a fixed value, but there is another source of absorption which should be considered; in a furnace small pieces of ash are carried forward in the flame, and this intercepts the radiant-energy charge from the body of the fire. This same charge is carried forward into the flues, and its dimension will be determined by the heat-capacity of such particles. Again, the interception of radiant-energy will be influenced partly by the nature of the ash, and I would like to ask Mr. Drakeley whether he has noted any variation in his results in the colour of the ash. The bomb-calorimeter will give a constant value for the British thermal units of the coal, but it will give no indication whatever of the action of the coal in the furnace. I would like Mr. Drakeley to carry his investigation a little further—into the furnace—and apply his data to the points suggested above.

Dr. GEORGE HICKLING (University of Manchester): It seems to me that Mr. Paton's remarks may be summarized thus: the ash coming out of the furnace carries away with it a certain amount of heat, which we can easily determine. It is dependent on its specific heat. The bomb-calorimeter does not show that, because at the end of the experiment it is practically at the temperature at which it started; therefore, the ash in it has given off all its heat. That heat is included in the calorific value of the coal. You do not get the whole of that in the inner furnace, because some of it is carried away with the ash coming out at high temperature.

Mr. DRAKELEY: In furnace work a larger percentage of the heat lost is due to carbon being left in the ash. Cinders are formed, and those contain combustible matter. I am not in a position to give any details regarding the actual furnace-work, but I consider that the colour of the ash will have no influence.

A MEMBER: Is it not the case that at the end of the bomb experiment the amount of heat lost in the ash is a negligible quantity?

Mr. DRAKELEY: Yes. The whole apparatus cools down to the same temperature. The rise in temperature in the bomb at the end of the experiment is not much above 7° Fahr., although at the moment of combustion the melting-point of platinum may be reached, namely, 3,180° Fahr.

Dr. HICKLING: It may be useful if I refer to some remarks which were made by Prof. Kendal of Leeds at the last meeting of the British Association on the question of the ash in coal. He pointed out—very usefully I think—that the ash in coal may be divided into three classes. In the first place, with the purest coal there must be an ash-content which represents the inorganic matter of the plants from which the coal was originally formed; secondly, there must be added to that ash from the mud deposited along with the coal; thirdly, there is the ash which one gets in the form of various secondary minerals, such as calcium carbonate, gypsum, etc. It would be very useful if Mr. Drakeley would, as far as he could, consider those three factors separately.

With regard to the point that the residue left on incinerating the shale seems to be very constant, I think there is a simple explanation. I presume Mr. Drakeley takes out from the seam parts which are definitely dirt-bands and incinerates those, then determines the percentage of ash left, which seems to come out constantly about 89 per cent. by weight. That is fairly obviously due to the fact that the dirt-bands are mainly ordinary mud—that is to say, mainly clay, and clay does tend to a very constant composition: it contains always 12 or 13 per cent. of combined water. It seems to me extremely probable that this combined water is driven off when the material is incinerated, and that would account for the fact that there is 89 per cent. of residue left. That, I think, is why the ordinary shale of the dirt-bands gives a very constant ash, and, so far as the impurity in the coal itself is of the same nature, that constancy will probably be maintained. On the other hand, if the coal contains any reasonable quantity of sparry material, that will have a much greater effect in proportion to its weight. The residue which it would leave on combustion would be something near the 56 per cent. which Mr. Drakeley gets in the case of chalk. Another type of impurity which clearly would give a very different effect is pyrites. It is a difficult matter to separate those various factors; but if the matter be regarded from that point of view, it may assist in a solution of the problem.

Mr. **Drakeley**: Certainly the impurity is not necessarily shale, and in the paper calcium carbonate is dealt with as a type of the sparry impurities.

With regard to the classes of ash, it is rather peculiar that in my paper on "Coal-washing" I brought that point out, but the paper was returned to me by the Publications Committee of The Institution of Mining Engineers with a request to reduce that section to a few lines. In consequence, the detailed classification of the types of impurities was omitted. The original account of that section, however, appeared in the *Colliery Guardian* of January 18th, 1918, page 126.

Mr. J. **Drummond Paton**: Is there any variation in the calorific value due to the colour of the ash?

Mr. **Drakeley**: The colour of the ash will have no influence whatever.

Dr. **Hickling**: It may be useful to put it in this way: if the question of colour comes in at all, it will only arise from the incomplete combustion of the material. As far as you are dealing with incombustible minerals you may take it as practically certain that when the coal is completely combusted the residue will be white; when it is black or dark, the colour is due to unburnt carbonaceous matter.

Mr. **Drakeley**: In determinations of the calorific value of coal, the relative humidity of the atmosphere in which the sample is air-dried is of importance. If the coal-samples are not subjected to the same conditions, the values fail to fall on the straight line. The whole of the coal used was subjected to air-drying only; but at the Wigan Mining and Technical College the ventilation keeps the relative humidity of the atmosphere in the laboratory fairly constant. Possibly in colliery laboratories it would be better to dry the coal at 105° Cent., or even at 100° Cent., than to subject it to air-drying.

A MEMBER: Is it possible to dry coal in gas?

Mr. DRAKELEY: It can be dried in nitrogen.

Mr. LAWS: Surely the whole idea of this method is to have something simple which can be done by an ordinary employé. If you are going to generate nitrogen and pass it over the coal, it will complicate the estimation tremendously. It seems to me that drying at 105° Cent. is the sensible way, and might be accepted as a standard method.

Dr. HICKLING: A very large amount of work has been done on that in the United States of America, and they have very definite regulations about the drying of coal.

Mr. LAWS: I think the regulations are that the coal is dried at 105°. The Department of Mines of the Dominion of Canada have adopted the method of passing over the coal a current of air which has been drawn through a solution of calcium chloride of a specific gravity 1·30, until the weight of the coal is constant. For the purpose of this determination simplicity is the aim, and it is impossible to get any method much simpler than to dry at 105°.

Mr. DRAKELEY: In this particular case I found air-drying was sufficiently satisfactory, owing to the fairly constant relative humidity of the atmosphere in the laboratory.

The further discussion of the paper was adjourned.

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE DANUM HOTEL, DONCASTER, NOVEMBER 9TH, 1918.

MR. W. D. LLOYD, PRESIDENT, IN THE CHAIR.

SOME ECONOMIC CONSIDERATIONS IN COKE-OVEN PRACTICE.

BY W. COLQUHOUN, ASSOC.M.INST.C.E.

Introductory.—Compared with the beehive coke-oven, the bye-product oven produces an equal quality of coke at a lower cost, uses less coal per ton of coke, and widens the range of coals available for coking. It has, therefore, a greater steadying influence on fluctuations in the cost of coke, and ultimately in that of iron.

Why do Beehive Ovens Survive?—The economic advantage is all in favour of bye-product practice, because the latter develops more fully the potential value of coal and conserves our national resources. It is, therefore, surprising that so much coke is still made in beehive ovens. It is not the large capital cost that stands in the way, for the value of the coal saved will itself pay the interest and depreciation charges. Nor is it altogether prejudice against the appearance and form of the coke. Two reasons are advanced for the survival of beehive ovens, namely:

(1) They may be started with little preparation and cost when the market is favourable, and stopped in less favourable times, whereas a bye-product plant must be operated continuously (especially if linked up to a colliery or ironworks for power purposes). The coal-owner decides whether to snatch a profit on occasion, or be content with an uninterrupted but smaller average profit.

(2) At a particular colliery the output of coking slack may fall short of the quantity that will most advantageously carry a bye-product plant through bad times. The essential complement of foremen and the operative team not on tonnage rates is capable of dealing with, say, forty discharges of coke per day, and the cost of labour per ton of coke is nearly doubled if there are only twenty discharges. A battery capable of forty discharges will consist of fifty ovens, assuming a coking period of 30 hours. These are favourable conditions in regard to the cost of labour, although, of course, smaller batteries may be, and

are, operated with financial success. But if a combination of interests can be brought about, the output of slack from two or more neighbouring collieries may be amalgamated with advantage to each.

Location of Ovens.—When there exists no special reason for linking up the ovens to the colliery, such a combination may advantageously join the blast-furnace owner and assemble the coals at the ironworks. The irregularities of supply attributed to particular circumstances at the colliery are then largely eliminated, and the ovens may be worked intensively and without those variations which rob the operation of coking of its economies. Whereas at the colliery the coals must be absorbed as they are produced, they may be mixed at the ironworks to give a more constant average content of volatile matter and produce a more uniform quality of coke, although one or more of the constituent coals may be of only indifferent coking quality.

FIG. 1.

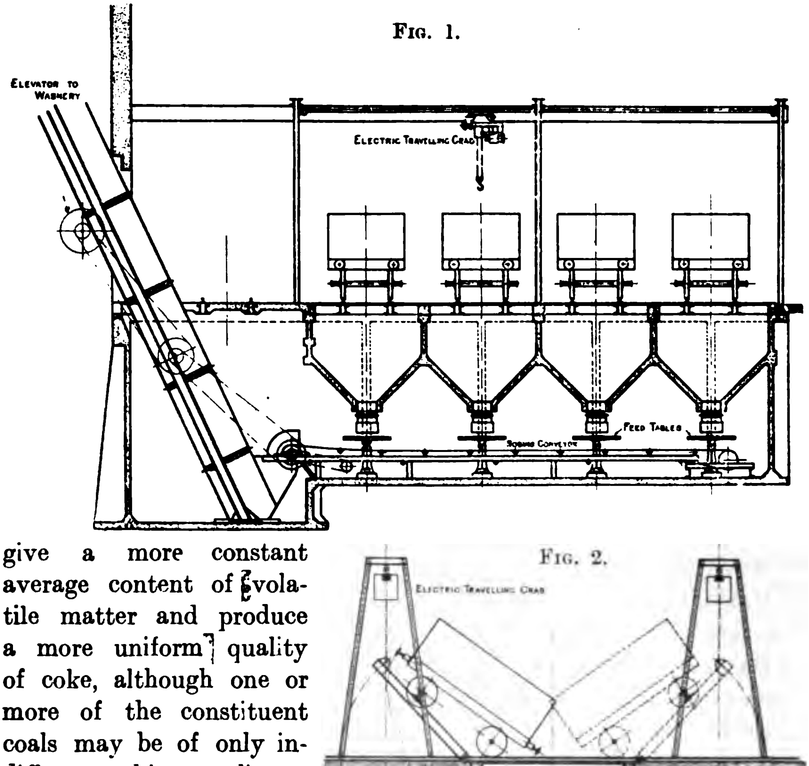
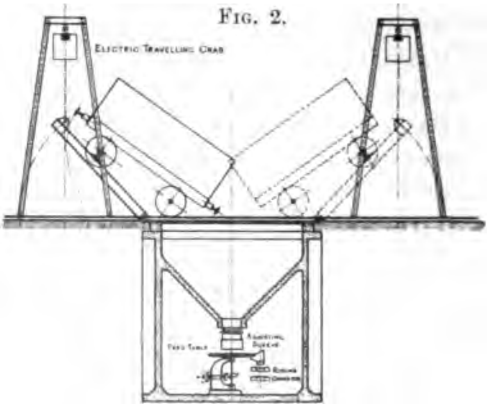


FIG. 2.



FIGS. 1 AND 2.—PLANT FOR MIXING COALS FOR COKING.

Mixing Coals.—Wherever the ovens may be located, the mixing of the coal ought to receive more attention than it does at present. It is due largely to the use of inferior coking slacks without adequate mixing that some of the bye-product coke produced to-day merits all the prejudice which attended its

earliest introduction. The blast-furnace manager wants coke uniform in quality, and at least constant in its imperfections. An intimate and uniform mixture of the slacks for bye-product ovens is not easily made and maintained over long periods. When derived from two or more seams, the slacks are not, in my opinion, sufficiently mixed by tipping alternate wagons into the raw coal-hopper, and by the turning-over they receive in the washery and drainage-bunkers. Better results are obtained from the arrangement shown in Figs. 1 and 2, consisting of several under-rail hoppers fitted with revolving feed-tables drawing regulated quantities from the several hoppers on to a common belt supplying the washery. The wagons are tipped by electric crabs, which span the four sidings.

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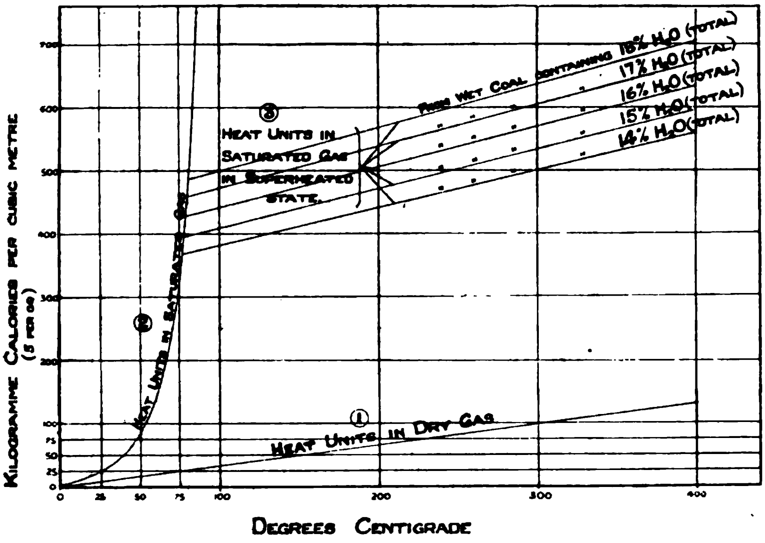

FIG. 3.—DIAGRAM OF TEMPERATURES BETWEEN 0° AND 400° CENT. FOR USE IN MEASURING THE WORK TO BE DONE BY THE CONDENSING APPARATUS.

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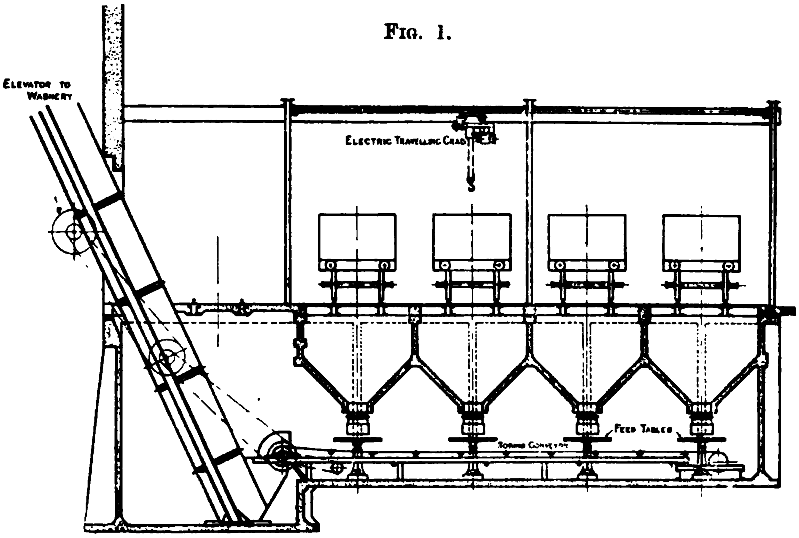
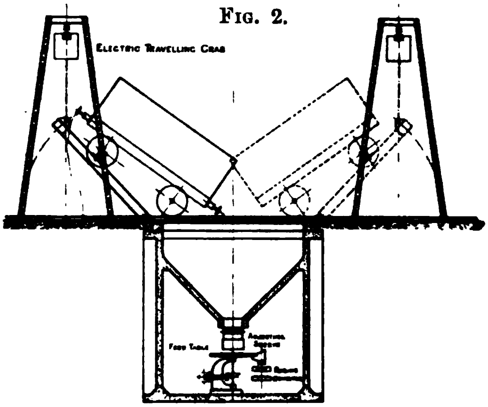


FIG. 2.



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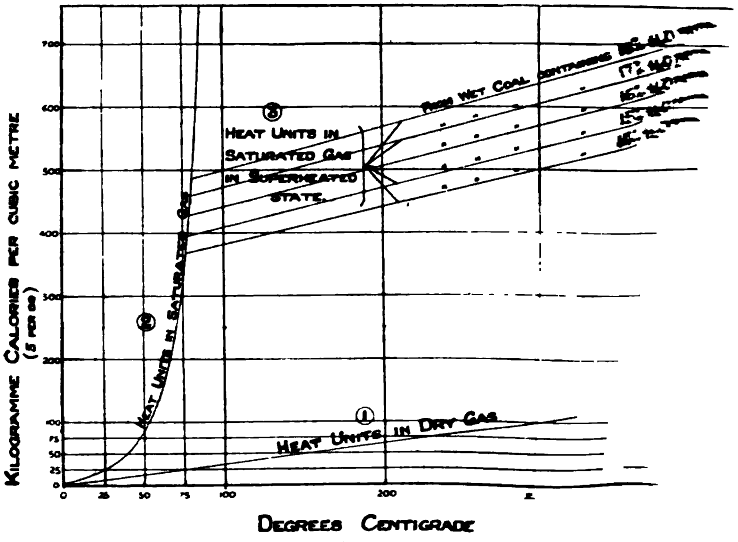

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MEASURING THE WORK TO BE DONE BY THE

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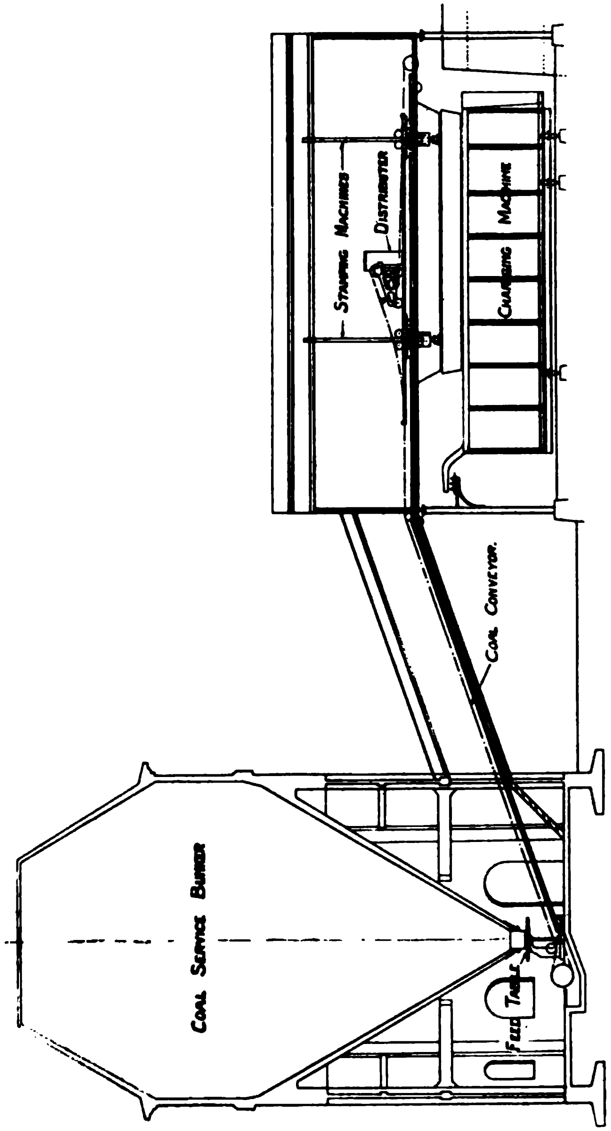
Coal Service Bunker
Feed Table
Coal Conveyor
Stamping Machines
Distributor
Charging Machine

FIG. 4.

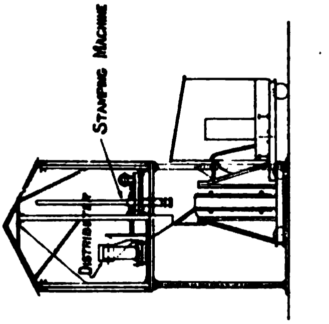
Distributor
Stamping Machine

FIG. 5.

FIGS. 4 AND 5.—SERVICE BUNKER FOR WASHED AND CRUSHED COAL.

ing the charge, it all has to be evaporated to steam in the oven—an appliance singularly unfitted for the purpose.

The work to be done later by the condensing apparatus may be measured in the accompanying diagram (Fig. 3) of temperatures between 0° and 400° Cent., showing that in gas at about 400° Cent. (when the cooling commences) in the case of coal with 14 per cent. total water, the heat contained in the water-vapour carried by the gas is 3·2 times the heat-units contained in the dry gas itself; and in coal with 18 per cent. total water more than 4·4 times the heat-units. On entering the condensers at about 100° Cent., these differences are respectively 10·5 and 14·1 times. If this contention is realized, every effort should be made to limit the amount of moisture left in the washed slack. None of the drying apparatus used in certain industries is practicable in this case, nor capable of dealing with the large quantities of material involved; but by insistence on 48 hours' drainage, and the introduction of a proportion of nuts or large coal, the moisture content can be kept under control. The extra profit on the direct sale of such nuts or large coal is apparently lost, but it may be regained several times over in the reduced cost and larger output of coke.

Service Bunkers.—For a battery of ovens charged with compressed cakes the best form of bunker for the washed and crushed coal is that shown in Figs. 4 and 5. It may be constructed in concrete or steel, and will completely empty itself. The coal is drawn by a revolving feed-table, in quantities regulated, first by the height of the cone of coal on the table, and secondly by the depth of cut of the scraper-arm. It is delivered on to a band-conveyor under the table, carried to the stamper runway, and distributed into the compression-box by an automatic reversing tripper, not in intermittent layers but continuously. With this arrangement the time taken to compress an 8-ton cake is from 12 to 18 minutes (varying with the fineness of crushing that the coal has received), whilst a 12-ton charge takes 24 minutes. Only a youth is necessary to attend to the operation of the table and conveyor.

Weighing.—The coal usually passes through the screens directly into the washery, and the weight of washed slack charged into the ovens is only ascertained from the weight of the coke and breeze made, based on the laboratory yield. It would be of great advantage if the washed slack could be weighed, and where a band-conveyor is in use, such as already described, it is quite practicable to instal one of the continuous type of weighing-machines.

Compressing.—The stamping of charges was first introduced in Germany for coal of semi-coking character that would not otherwise make good coke; but the operation now has a wider application, and serves to improve the quality of many British cokes. Its adoption in this country was retarded by the troubles due to unreliable and cheap machinery imported from Germany, and by the slow and unequal heating of some of the earlier ovens. In such circumstances the oven output was reduced and the advantages of compressed charges were discredited. Careful tests made in Semet-Solvay ovens on coals containing from 26 to 28 per cent. of volatile matter show that the weight of the charge is increased approximately 30 per cent., which is reduced by the longer coking time to a net gain in production of about 13 per cent. If it is established by trial that the quality of a coke is improved by compression, that operation is preferable to top-charging in many ways. The top of the charge has the same density as the bottom, and the coke is therefore more uniform; the proportion of breeze is reduced; the charge is a constant quantity and a measure of the capacity of the plant; the capacity is maintained at a maximum independently of the skill or care of workmen; the oven being completely filled, the amount of free space on top of the charge, and consequently the degradation of bye-products, is minimized; the gas off-take may be in the centre of the oven length, and the path of the gases shortened; finally, except in the smaller plants, the labour cost per ton of production is definitely below that of the best system of top-charging.

Size of Oven.—The number of charging and discharging operations per shift is usually limited by the capacity of the workmen, or by trade-union rules, and therefore the operation of the battery becomes more economical with every increase in the weight of the charge. In recognition of this, the 12-ton oven (11·65 tons of dry coal) is an accomplished fact in this country, having been built at Hoyland Silkstone Colliery and Thorncliffe Iron Works. For a given output there are fewer interruptions for recharging, and the number of ovens opened to the air is reduced, as well as the proportion of soft coke from the top and ends.

Let us, in passing, compare British with American practice, in which the standard oven now holds from 15 to 16 tons. The coal cannot be stamped, the height of the stamped cake being too great, and, being unwashed, it cannot in any event be compressed: to add water merely for that purpose would be indefensible. The higher thermal conductivity of their standard silica construction, the higher working temperature used in practice, and the relative dryness of the coal together enable them to coke at double the rate obtaining here, namely, in an average time of 50 minutes per inch of width. The resulting large output of coke yields a quicker return on the capital outlay, but, as may be expected, at the expense of part of the bye-products. It is estimated that the recoverable bye-products are reduced by 20 per cent. for tar and benzol and 10 per cent. for sulphate. Although the value of the bye-products sacrificed is of small importance compared with the value of the coke, this waste does not commend itself.

Oven Taper.—The retarding influence on output due to the taper in an oven is not sufficiently realized. The wide end prolongs the coking time, and this cannot well be corrected by a proportionate supply of heat, because it is at this end that the flue-walls are narrowest. Coking is completed at the narrow end some three or four hours before this takes place at the wide end, and the temperature at the wide end never reaches that of the narrow end, all of which tends to unequal coking in the batch This defect has frequently been observed.

Since the relief afforded in pushing out a batch with two inches of taper in a length of 33 feet is only that due to $\frac{1}{16}$ inch of taper per foot of movement, it is questionable whether it is worth anything. It is really objectionable in respect to stamped charges, unless the cake has a similar taper and is charged from the hearth side.

Horizontal Flues.—The temperature of combustion of coke-oven gas is so high that the bricks will fuse unless an excess of air is used, the amount of which will vary with the temperature to which the air has been pre-heated. In the Semet-Solvay oven the excess air is admitted only into the top flue, where it is heated to the temperature of the products of combustion, and furnishes the air required in the second and subsequent flues. In these flues there is no danger of fusion, owing to the presence of burnt products from the flues above; combustion in the whole system can therefore be so regulated that the theoretical quantity of air is only slightly exceeded in order to ensure complete combustion. Such regulation involves attention, since the combustion of the gas is affected directly by the increasing temperature of the flue-walls as the coking of a charge proceeds.

In vertical flues the excess air necessary for safety is introduced at every gas-admission, and is not used up in succeeding flues, but finally passes up the stack at a temperature which may represent a considerable loss in heat-units. I am of opinion that no other condition is possible in vertical-flue ovens: the air and gas cannot be regulated from hour to hour, and, therefore, after the first setting, they are not regulated at all. In practice, certain types of vertical flues show unequal heating of the walls when worked as waste-heat ovens; but the same ovens built with regenerators, with the air pre-heated to

1,000° Cent., become at once more lively and coke in shorter time. This improved working may probably be attributed to the flooding of the flues with larger volumes of gas and air corresponding to the higher temperature.

Horizontal flues have survived criticism, and there is even a reversion of opinion in their favour. The distribution of heat is quite uniform, and in view of the very large number of Simon-Carvés, Huessener, Simplex, and Semet-Solvay ovens built during the last ten years, any doubts as to the efficiency of the type can no longer exist.

In the case of coal with 28 per cent. of volatile matter and 12 per cent. of moisture, the average speed of coking of the Semet-Solvay oven, up to, say, 20 inches wide, is 90 minutes per inch of width.

Surplus Energy.—It is customary to assume that the whole of the surplus gas from regenerative ovens—say, 5,500 cubic feet per ton of dry coal—is available as surplus energy, and to overlook the fact that the internal requirements of the plant must first be satisfied. In order to ascertain these, the following data may be taken for a battery coking 350 tons of washed slack per day—say, 310 tons in the dry state:—

(1) REGENERATIVE OVENS AND GAS-ENGINES.

		British thermal units per hour.
Surplus gas at 450 B.T.U. per cubic foot, 2,475,000 B.T.U. per ton of dry coal × 13 tons per hour ..		32,175,000
Deduct (*a*) Power required to run washery, crushers, water and other pumps, exhauster, charging and discharging machinery, etc. Mean of day and night load, 400 brake-horsepower, say 300 kilowatts at switchboard. 300 kilowatts × 15,075 B.T.U. per kilowatt-hour	4,522,500	
(*b*) Steam for ammonia and benzol stills, boiler-feed pump, steaming out and miscellaneous purposes, including 10-per-cent. steam-distribution losses (385 pounds per ton of coal coked), 5,000 pounds per hour × 3·5* cubic feet of gas per pound of steam × 450 B.T.U. per cubic foot	7,875,000	
		12,397,500
		19,777,500

The surplus energy available is therefore $\frac{19,777,500 \text{ B.T.U.}}{15,075 \text{ B.T.U. per kilowatt}}$ =1,311 kilowatts.

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* NOTE.—This is reduced to 2·6 cubic feet in Bonecourt boilers.

(2) Waste-heat Ovens and Boilers.

A similar battery of waste-heat ovens (the waste-heat and surplus gas combined) will raise 2,000 pounds of steam per ton of coal.

		Pounds per hour.
Total steam, 13 tons coal × 2,000 pounds		26,000
Deduct (*a*) 300 kilowatts for internal requirements as before, at 25 pounds of steam per kilowatt-hour	7,500	
(*b*) Steam for stills, etc., as above ..	5,000	12,500
		13.500

The surplus energy in this case is accordingly 13,500 pounds ÷ 25 pounds = 540 kilowatts. (Note.—These figures do not take into consideration the maximum day load, and cannot therefore be taken as a basis for the size of the generating sets. From that point of view the internal consumption and surplus combined would indicate for the day load two gas-engine sets of 800 kilowatts each for (1) the regenerative ovens, and two steam-turbine sets of 500 kilowatts each for (2) the waste-heat ovens, exclusive of stand-bys in each instance.)

(3) Waste-heat Ovens and Gas-engines and Boilers together.

If the surplus gas is used in gas-engines instead of under boilers, the waste-heat ovens will yield a larger amount of power than 540 kilowatts. The waste-heat will raise 1,400 pounds of steam per ton of coal, and the surplus gas will amount to, say, 2,200 cubic feet per ton of coal.

	Pounds.
Total steam, 13 tons of coal × 1,400 pounds	18,200
Deduct internal requirements as before	12,500
Total	5,700
	Kilowatts.
Power from steam 5,700 ÷ 25 cubic feet	228
Power from gas $\frac{2,200 \text{ cubic feet} \times 450 \text{ B.T.U.}}{15,075 \text{ B.T.U.}}$ ..	657
Total power	885

If, then, the gas is burnt in gas-engines, more power is derivable from the regenerative than from the waste-heat oven, but the regenerative oven, which costs more, is not *per se* more economical. There is no economy in using surplus gas for raising steam, but rather the reverse. It should not be used for that purpose if coke-breeze is available. The combination of regenerative ovens and boilers is therefore defensible only in sample is air-dried is of importance. If the coal-samples are not subjected to the same conditions, the values fail to fall on the straight line. The whole of the coal used was subjected to air-drying only; but at the Wigan Mining and Technical College the ventilation keeps the relative humidity of the atmosphere in the laboratory fairly constant. Possibly in colliery laboratories it would be better to dry the coal at 105° Cent., or even at 100° Cent., than to subject it to air-drying.

A MEMBER: Is it possible to dry coal in gas?

Mr. DRAKELEY: It can be dried in nitrogen.

Mr. LAWS: Surely the whole idea of this method is to have something simple which can be done by an ordinary employé. If you are going to generate nitrogen and pass it over the coal, it will complicate the estimation tremendously. It seems to me that drying at 105° Cent. is the sensible way, and might be accepted as a standard method.

Dr. HICKLING: A very large amount of work has been done on that in the United States of America, and they have very definite regulations about the drying of coal.

Mr. LAWS: I think the regulations are that the coal is dried at 105°. The Department of Mines of the Dominion of Canada have adopted the method of passing over the coal a current of air which has been drawn through a solution of calcium chloride of a specific gravity 1·30, until the weight of the coal is constant. For the purpose of this determination simplicity is the aim, and it is impossible to get any method much simpler than to dry at 105°.

Mr. DRAKELEY: In this particular case I found air-drying was sufficiently satisfactory, owing to the fairly constant relative humidity of the atmosphere in the laboratory.

The further discussion of the paper was adjourned.

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE DANUM HOTEL, DONCASTER, NOVEMBER 9TH, 1918.

MR. W. D. LLOYD, PRESIDENT, IN THE CHAIR.

SOME ECONOMIC CONSIDERATIONS IN COKE-OVEN PRACTICE.

BY W. COLQUHOUN, ASSOC.M.INST.C.E.

Introductory.—Compared with the beehive coke-oven, the bye-product oven produces an equal quality of coke at a lower cost, uses less coal per ton of coke, and widens the range of coals available for coking. It has, therefore, a greater steadying influence on fluctuations in the cost of coke, and ultimately in that of iron.

Why do Beehive Ovens Survive?—The economic advantage is all in favour of bye-product practice, because the latter develops more fully the potential value of coal and conserves our national resources. It is, therefore, surprising that so much coke is still made in beehive ovens. It is not the large capital cost that stands in the way, for the value of the coal saved will itself pay the interest and depreciation charges. Nor is it altogether prejudice against the appearance and form of the coke. Two reasons are advanced for the survival of beehive ovens, namely:

(1) They may be started with little preparation and cost when the market is favourable, and stopped in less favourable times, whereas a bye-product plant must be operated continuously (especially if linked up to a colliery or ironworks for power purposes). The coal-owner decides whether to snatch a profit on occasion, or be content with an uninterrupted but smaller average profit.

(2) At a particular colliery the output of coking slack may fall short of the quantity that will most advantageously carry a bye-product plant through bad times. The essential complement of foremen and the operative team not on tonnage rates is capable of dealing with, say, forty discharges of coke per day, and the cost of labour per ton of coke is nearly doubled if there are only twenty discharges. A battery capable of forty discharges will consist of fifty ovens, assuming a coking period of 30 hours. These are favourable conditions in regard to the cost of labour, although, of course, smaller batteries may be, and

are, operated with financial success. But if a combination of interests can be brought about, the output of slack from two or more neighbouring collieries may be amalgamated with advantage to each.

Location of Ovens.—When there exists no special reason for linking up the ovens to the colliery, such a combination may advantageously join the blast-furnace owner and assemble the coals at the ironworks. The irregularities of supply attributed to particular circumstances at the colliery are then largely eliminated, and the ovens may be worked intensively and without those variations which rob the operation of coking of its economies. Whereas at the colliery the coals must be absorbed as they are produced, they may be mixed at the ironworks to give a more constant average content of volatile matter and produce a more uniform quality of coke, although one or more of the constituent coals may be of only indifferent coking quality.

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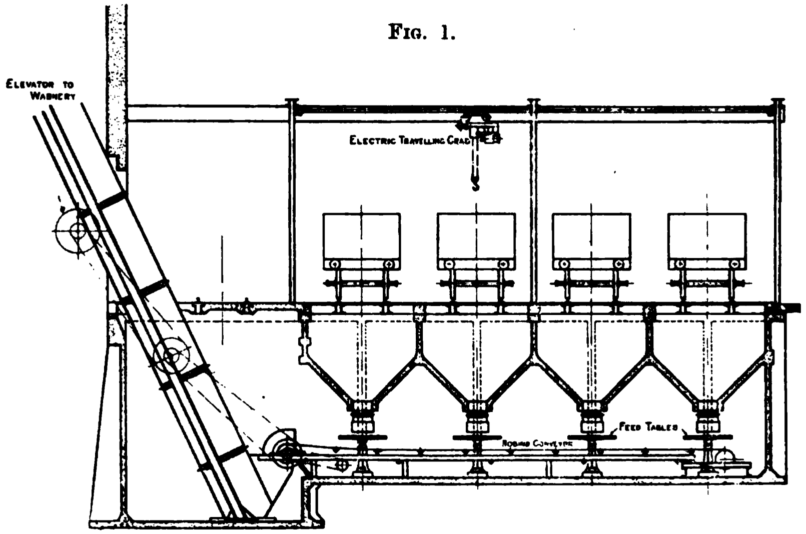

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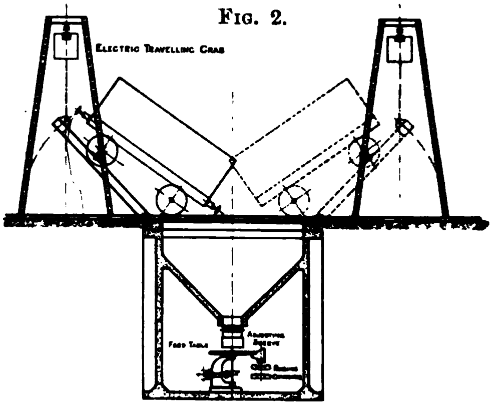

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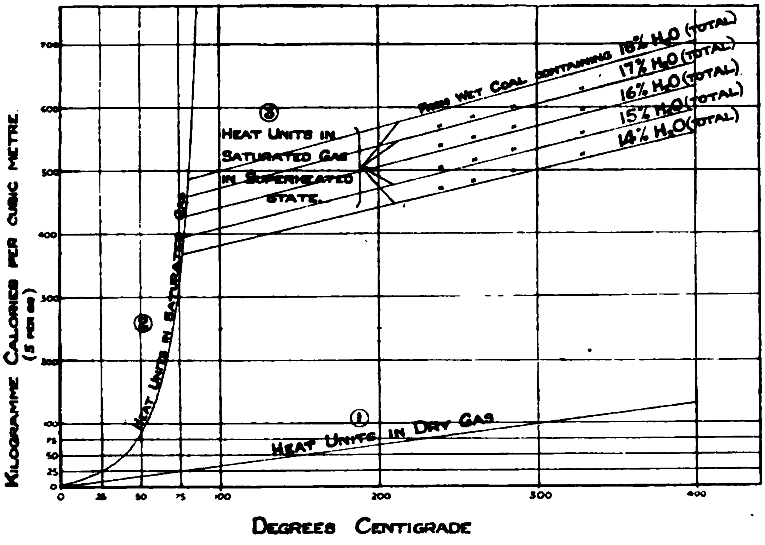

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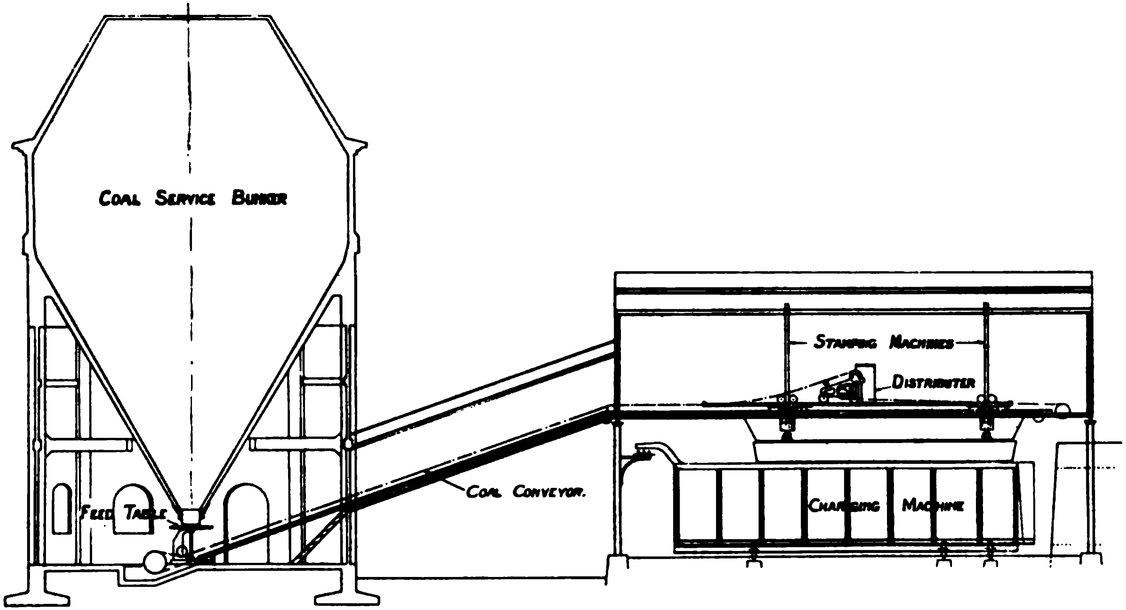
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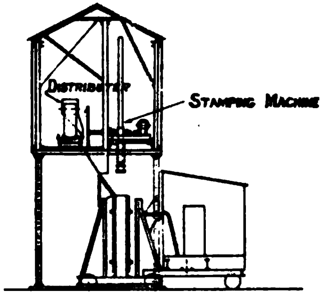
Distributer
Charging Machine

Fig. 4.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Compressing.—The stamping of charges was first introduced in Germany for coal of semi-coking character that would not otherwise make good coke; but the operation now has a wider application, and serves to improve the quality of many British cokes. Its adoption in this country was retarded by the troubles due to unreliable and cheap machinery imported from Germany, and by the slow and unequal heating of some of the earlier ovens. In such circumstances the oven output was reduced and the advantages of compressed charges were discredited. Careful tests made in Semet-Solvay ovens on coals containing from 26 to 28 per cent. of volatile matter show that the weight of the charge is increased approximately 30 per cent., which is reduced by the longer coking time to a net gain in production of about 13 per cent. If it is established by trial that the quality of a coke is improved by compression, that operation is preferable to top-charging in many ways. The top of the charge has the same density as the bottom, and the coke is therefore more uniform; the proportion of breeze is reduced; the charge is a constant quantity and a measure of the capacity of the plant; the capacity is maintained at a maximum independently of the skill or care of workmen; the oven being completely filled, the amount of free space on top of the charge, and consequently the degradation of bye-products, is minimized; the gas off-take may be in the centre of the oven length, and the path of the gases shortened; finally, except in the smaller plants, the labour cost per ton of production is definitely below that of the best system of top-charging.

Size of Oven.—The number of charging and discharging operations per shift is usually limited by the capacity of the workmen, or by trade-union rules, and therefore the operation of the battery becomes more economical with every increase in the weight of the charge. In recognition of this, the 12-ton oven (11·65 tons of dry coal) is an accomplished fact in this country, having been built at Hoyland Silkstone Colliery and Thorncliffe Iron Works. For a given output there are fewer interruptions for recharging, and the number of ovens opened to the air is reduced, as well as the proportion of soft coke from the top and ends.

Let us, in passing, compare British with American practice, in which the standard oven now holds from 15 to 16 tons. The coal cannot be stamped, the height of the stamped cake being too great, and, being unwashed, it cannot in any event be compressed: to add water merely for that purpose would be indefensible. The higher thermal conductivity of their standard silica construction, the higher working temperature used in practice, and the relative dryness of the coal together enable them to coke at double the rate obtaining here, namely, in an average time of 50 minutes per inch of width. The resulting large output of coke yields a quicker return on the capital outlay, but, as may be expected, at the expense of part of the bye-products. It is estimated that the recoverable bye-products are reduced by 20 per cent. for tar and benzol and 10 per cent. for sulphate. Although the value of the bye-products sacrificed is of small importance compared with the value of the coke, this waste does not commend itself.

Oven Taper.—The retarding influence on output due to the taper in an oven is not sufficiently realized. The wide end prolongs the coking time, and this cannot well be corrected by a proportionate supply of heat, because it is at this end that the flue-walls are narrowest. Coking is completed at the narrow end some three or four hours before this takes place at the wide end, and the temperature at the wide end never reaches that of the narrow end, all of which tends to unequal coking in the batch This defect has frequently been observed.

Since the relief afforded in pushing out a batch with two inches of taper in a length of 33 feet is only that due to $\frac{}{16}$ inch of taper per foot of movement, it is questionable whether it is worth anything. It is really objectionable in respect to stamped charges, unless the cake has a similar taper and is charged from the hearth side.

Horizontal Flues.—The temperature of combustion of coke-oven gas is so high that the bricks will fuse unless an excess of air is used, the amount of which will vary with the temperature to which the air has been pre-heated. In the Semet-Solvay oven the excess air is admitted only into the top flue, where it is heated to the temperature of the products of combustion, and furnishes the air required in the second and subsequent flues. In these flues there is no danger of fusion, owing to the presence of burnt products from the flues above; combustion in the whole system can therefore be so regulated that the theoretical quantity of air is only slightly exceeded in order to ensure complete combustion. Such regulation involves attention, since the combustion of the gas is affected directly by the increasing temperature of the flue-walls as the coking of a charge proceeds.

In vertical flues the excess air necessary for safety is introduced at every gas-admission, and is not used up in succeeding flues, but finally passes up the stack at a temperature which may represent a considerable loss in heat-units. I am of opinion that no other condition is possible in vertical-flue ovens: the air and gas cannot be regulated from hour to hour, and, therefore, after the first setting, they are not regulated at all. In practice, certain types of vertical flues show unequal heating of the walls when worked as waste-heat ovens; but the same ovens built with regenerators, with the air pre-heated to

1,000° Cent., become at once more lively and coke in shorter time. This improved working may probably be attributed to the flooding of the flues with larger volumes of gas and air corresponding to the higher temperature.

Horizontal flues have survived criticism, and there is even a reversion of opinion in their favour. The distribution of heat is quite uniform, and in view of the very large number of Simon-Carvés, Huessener, Simplex, and Semet-Solvay ovens built during the last ten years, any doubts as to the efficiency of the type can no longer exist.

In the case of coal with 28 per cent. of volatile matter and 12 per cent. of moisture, the average speed of coking of the Semet-Solvay oven, up to, say, 20 inches wide, is 90 minutes per inch of width.

Surplus Energy.—It is customary to assume that the whole of the surplus gas from regenerative ovens—say, 5,500 cubic feet per ton of dry coal—is available as surplus energy, and to overlook the fact that the internal requirements of the plant must first be satisfied. In order to ascertain these, the following data may be taken for a battery coking 350 tons of washed slack per day—say, 310 tons in the dry state:—

(1) REGENERATIVE OVENS AND GAS-ENGINES.

		British thermal units per hour.
Surplus gas at 450 B.T.U. per cubic foot, 2,475,000 B.T.U. per ton of dry coal × 13 tons per hour ..		32,175,000
Deduct (*a*) Power required to run washery, crushers, water and other pumps, exhauster, charging and discharging machinery, etc. Mean of day and night load, 400 brake-horse-power, say 300 kilowatts at switchboard. 300 kilowatts × 15,075 B.T.U. per kilowatt-hour	4,522,500	
(*b*) Steam for ammonia and benzol stills, boiler-feed pump, steaming out and miscellaneous purposes, including 10-per-cent. steam-distribution losses (385 pounds per ton of coal coked), 5,000 pounds per hour × 3·5[*] cubic feet of gas per pound of steam × 450 B.T.U. per cubic foot	7,875,000	
		12,397,500
		19,777,500

The surplus energy available is therefore $\frac{19{,}777{,}500 \text{ B.T.U.}}{15{,}075 \text{ B.T.U. per kilowatt}}$ =1,311 kilowatts.

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[*] NOTE.—This is reduced to 2·6 cubic feet in Bonecourt boilers.

(2) WASTE-HEAT OVENS AND BOILERS.

A similar battery of waste-heat ovens (the waste-heat and surplus gas combined) will raise 2,000 pounds of steam per ton of coal.

		Pounds per hour.
Total steam, 13 tons coal × 2,000 pounds		26,000
Deduct (*a*) 300 kilowatts for internal requirements as before, at 25 pounds of steam per kilowatt-hour	7,500	
(*b*) Steam for stills, etc., as above ..	5,000	
		12,500
		13.500

The surplus energy in this case is accordingly 13,500 pounds ÷ 25 pounds = 540 kilowatts. (Note.—These figures do not take into consideration the maximum day load, and cannot therefore be taken as a basis for the size of the generating sets. From that point of view the internal consumption and surplus combined would indicate for the day load two gas-engine sets of 800 kilowatts each for (1) the regenerative ovens, and two steam-turbine sets of 500 kilowatts each for (2) the waste-heat ovens, exclusive of stand-bys in each instance.)

(3) WASTE-HEAT OVENS AND GAS-ENGINES AND BOILERS TOGETHER.

If the surplus gas is used in gas-engines instead of under boilers, the waste-heat ovens will yield a larger amount of power than 540 kilowatts. The waste-heat will raise 1,400 pounds of steam per ton of coal, and the surplus gas will amount to, say, 2,200 cubic feet per ton of coal.

	Pounds.
Total steam, 13 tons of coal × 1,400 pounds	18,200
Deduct internal requirements as before	12,500
Total	5,700
	Kilowatts.
Power from steam 5,700 ÷ 25 cubic feet	228
Power from gas $\frac{2{,}200 \text{ cubic feet} \times 450 \text{ B.T.U.}}{15{,}075 \text{ B.T.U.}}$ ..	657
Total power	885

If, then, the gas is burnt in gas-engines, more power is derivable from the regenerative than from the waste-heat oven, but the regenerative oven, which costs more, is not *per se* more economical. There is no economy in using surplus gas for raising steam, but rather the reverse. It should not be used for that purpose if coke-breeze is available. The combination of regenerative ovens and boilers is therefore defensible only in the event of the boilers being remote from the battery, or if the full power is wanted during the day only, in which case the overnight output of gas may be stored.

If the maximum kilowatt production from a given amount of energy were the only consideration, the advantage is overwhelmingly on the side of the gas-engine. The greater cost of the gas-plant, its higher operating cost, and its low efficiency at low loads are of no consequence beside the outstanding fact that, as compared with the boiler and turbo-generator, the same amount of energy gives some 2½ times more power. But while the maximum of power may represent the ideal point of view, in most instances there are other considerations to be weighed. For example, when the maximum power consumption is once established, the coke-ovens must be made to live up to it, and there is no room for changes in the fuel market, strikes, irregularities of supply, or variations of any kind in the output of potential thermal units. The plant then becomes a gas-producer plant. The gas-engine has not kept pace with the steam-turbine in its development, either in size of units or in simplicity. It is still subject to improvements or to inventions of even a revolutionary character. With coke-oven gas as fuel, the reliability of the gas-engine is more or less in doubt; thus, in an iron and steel-works the undiluted gas from the coke-ovens would not be preferred to blast-furnace gas for power purposes, but would be sent to the steel furnaces. Finally, as some steam is required at every coke-oven plant, the size of the plant and proportion of steam necessary must be taken into consideration. For these and other reasons peculiar to each plant no general rule can be laid down.

Producer-gas.—The oven-gas may be released for other purposes by heating the ovens with producer-gas. In that event the steam required for the ammonia and benzol stills will be raised by direct firing with coal, along with the steam required for the producers, because direct firing is essentially more economical than gas-firing for boilers. Owing to the large capital expenditure involved, a producer installation with ammonia recovery is not applicable to small coke-oven plants. Assuming, therefore, a battery coking 620 tons per day, or 226,300 tons per annum, the producer fuel required will be 36,500 tons per annum, and the steam as follows:—

	Tons.
For producers	63,875
„ stills	38,925
Total	102,800

The equivalent of this in boiler fuel will be 102,800 ÷ 6 = 17,133 tons, and the cost of gas will be as follows:—

	£
Producer fuel, 36,500 tons at 10s. per ton	18,250
Boiler fuel, 17,133 tons at 12s. per ton.	10,280
Producer wages, 36,500 tons at 1s. 6d. per ton	2,737
Boiler wages, 17,133 tons at 9d. per ton	642
Repairs, stores, and maintenance, 36,500 tons at 9d. per ton	1,368
Interest and depreciation, 10 per cent. on cost of plant, say, £120,000	12,000
Sulphuric acid, 1,140 tons at £2 per ton	2,280
Bags and packing sulphate, 1,140 tons at 7s. per ton	399
	£47,956
Less sulphate (70 pounds per ton), 1,140 tons at £13 net at works	14,820
Net cost of gas per annum	£33,136

At these pre-war prices (which are merely suggested for the purpose of this statement), the cost of producer-gas is £33,136 ÷ 226,300 tons, equal to, say, 3s. per ton of coal carbonized. This represents the cost of releasing a further 5,000 cubic feet of gas, or 2¼ million British thermal units per ton of coal carbonized, to add to the surplus 5,500 cubic feet already obtained as a bye-product.

Oven-gas for Steel-works.—It is interesting to conceive a self-subsistent works embracing coke-ovens, blast-furnaces, and steel-works. The ovens have to furnish the coke required by the blast-furnaces as well as the gas required in the steel-works, and they will themselves be heated with blast-furnace gas. Assuming a coal yielding 70 per cent. of coke and a coke-consumption (under Lincolnshire conditions) of 30 cwt. per ton of iron; adopting Greiners' figure of 9,800 (say, 10,000) cubic feet of coke-oven gas per ton of ingots made in the steel furnace; increasing this to 13,000 cubic feet to cover for the heating furnaces, so that all gas-producers are eliminated: then per 1,000 tons of ingots (all pig-iron charges) 1,000 × (105 ÷ 100) = 1,050 tons of iron are required; for 1,050 tons of iron, 1,050 × 1½ = 1,575 tons of coke; for 1,575 tons of coke, 1,575 × (100 ÷ 70) = 2,250 tons of coal (dry). The yield of coke-oven gas will be 22½ millions, of which 13 millions will go to the steel-works and 9½ millions will remain for other purposes, including that considerable margin which interconnected departments demand (arising from shortage of coal to the ovens, irregularity of gas from the blast-furnaces, etc.).

The blast-furnaces in their turn yield a sufficient supply of gas for their own services and for the coke-ovens as well.

	Cubic feet.
Blast-furnace gas required to coke a ton of coal ...	25,275
or, per ton of pig-iron produced, 2,250 × 25,275 ÷ 1,050 ...	54,160

The quantity of blast-furnace gas produced per ton of pig-iron (on Lincolnshire ore and 30 cwts. of coke) and its apportionment. is approximately as follows·—

	Cubic feet.
Heating blast	100,000
Gas blowing-engines	30,000
Auxiliary electric power (ore-handling, hoists, pumping, lighting, etc.)	5,000
Balance for disposal	115,000
Total blast-furnace gas	250,000

Low-temperature Carbonization.—Indefinite and incomplete carbonization of coals of good coking quality is economically unsound, and (until after the demand for metallurgical coke is satisfied) it is not in the best interests of the country, whether the coke is destined for domestic use or for gasifying in producers. The most liberal concessions as to the yields of fuel oils obtained and of other products do not justify it. The treatment, therefore, is most suitable for coals inconvertible into metallurgical coke, and has no place in this discussion.

Smoke-prevention.—The smoke given off during charging is a nuisance to the neighbourhood and to the workmen, which may be mitigated to some extent at least by making a connexion between the stand-pipe and a collecting-flue. The connexion is usually made with a portable bend, and is thus definitely broken when the bend is removed. This is to be preferred to any coupling of a permanent character, defects in which may lead to leakages. The collecting-flue is continually becoming choked with soot, even when arrangements are made to keep it at a red heat, and it is therefore quite usual to find it out of service. A higher draught is desirable than that given by the chimney, and a steam-injector exhaust may be provided, blowing through, and protected by, a water-seal. The various methods of taking off smoke are described in Ohnesorge's paper, *Stahl u. Eisen*, September 4th, 1913, pages 1,471-1,477.

Self-sealing Doors.—When a charging larry is part of the equipment, the winches necessary for oven doors of the lifting type require more room on top of the ovens than can be spared. The substitution of a door removable outwards and sideways by the ramming machine, or by a travelling door crane, is a natural development, and presents no mechanical difficulties; but the "self-sealing" feature of the doors is not yet satisfactorily solved; and their maintenance is a formidable matter.

Coke-quenching and Handling.—The inclined coke-hearth finds most favour in this country. Although costly in the first instance, it is a permanency and ideal for quenching, and a stock may be held on the bench to tide over interruptions in railway traffic.

The coke is removable from the foot of the slope either by conveyor, the upkeep and drive of which costs nearly 2d. per ton of coke, or by hand-grips directly into trucks; but if there is sufficient natural fall in the ground upon which the battery is built, the coke might slide off an inclined hearth on to a coke-car, which would make quite a perfect arrangement.

The car is an alternative to the inclined hearth, and the lost stocking-room is, in a measure, compensated for by sliding the coke off the car on to a bench or screen. The relatively light weight of a car admits of its elevation by incline or hoist to the higher level required for screens. Drenched with quenching-water and steam, it has only a short life, but it is cheap to replace. It is preferably built in two parts, mounted on four standard railway axles and wheels, with a large floor area—not less than 50 by 13 feet for an 8-foot oven, and 60 by 14 feet for a 10-foot oven. The coke is more readily quenched, and "steams off" drier, if spread thinly on a large floor.

Apparatus (such as Moore's or Goodall's) carrying motors and gearing, weighing ten times more than the coke it carries, and subject to the action of quenching-water, breeze, and steam, is to be avoided unless the site is of such a nature as to make it obligatory. In that case the machine should be duplicated so as to avoid a complete interruption when there is a breakdown.

American practice differs from ours, just as the conditions differ. A batch of coke weighing from 10 to 12 tons cannot be spread thinly without the dimensions of the car exceeding practical limits, and the car is therefore loaded deeper, with the inclined floor measuring only about 40 by 10 feet. It is mounted on double bogie wheels at each end, and is adapted to run on standard tracks with other traffic. Again, the batteries are often so large that only a few minutes elapse between the discharges, and there is no time to quench and steam off in front of the oven. The quenching is therefore done at a station at the end of the battery, with the advantage that there is no cloud of steam to obstruct the workmen and attack the oven ironwork. The coke is quenched in the car at the station in some instances; but in order to release the car for further service and preserve its life, the present practice tends towards a partial quenching in the car, completed on a sloping bench or screen. If we contemplate similar practice, the arrangements must necessarily conform to those in vogue in America; the surface of coke exposed to the air must be reduced, and the ramming-out of the coke and moving of the car must be more smartly done.

Ammonia.—Although up to 50 per cent. of the nitrogen may be liberated in coking, only from 13 to 16 per cent. are recovered as ammonia. We have no control over the proportion recovered, and have to be satisfied with what is yielded from any coal by the conditions of operation. We know only that the temperature at which it is formed differs with different coals. Fortunately, despite these limitations, it is recovered at a lower figure than the cost of fixing nitrogen in any other chemical combination.

We know that the thermal decomposition of the gases that are evolved is inappreciable below 870-900° Cent., and this fixes the temperature of operation at the top of the oven-chamber. We know that when the coal is wet, as compared with dry, the state of dilution of the gas with water-vapour protects the constituents of the gas from dissociation into its elements at that temperature. We know also the importance of equality of pressures in the oven; if it were practicable to have more than one ascension-pipe, and an even pressure throughout the length of the collecting-main, the pressure in individual ovens might be more nearly uniform than is possible in our present practice, and this would result in larger yields of ammonia.*

A contributory improvement is furnished by avoiding high mains and long ascension-pipes, which are liable to become coated internally with carbon; by charging so as to fill to the crown of the oven and minimize the hot surface of brickwork exposed; and by placing the ascension-pipe in the middle of the oven, if possible, to equalize the travel of the gases.

The catalytic effect of iron and its oxides at the temperature at which ammonia is dissociated is most unfavourable for the yield.† In one case it has been observed that an increase of iron in the ash content of a coal, over a term of years, had a corresponding adverse effect upon the yield of ammonia.

Calcium compounds have a catalytic effect of a contrary character, a fact that has proved attractive to investigators for many years. Campbell (see last citation) found that the addition of 2 per cent. of lime increased the yield of sulphate by 10 to 15 per cent.; Knublauch added 2½ per cent. for an increase of 30 per cent.; Schreiber (*Journal für Gasbeleuchtung*, 1906, page 925-929) added 3½ per cent. for an increase of 20 per cent.; whilst Patterson (at Cheltenham gas-works, *Journal of Gas Lighting*, 1911, Vol. CXVI., pages 95-97 and 449) obtained an increase of 13 per cent. But apart from the fact that part of the sulphur is fixed which would otherwise be volatilized, no process is admissible which adds to the ash content of metallurgical coke. Dr. Diehl proposed the use of limestone instead of lime, on the supposition that the volatile sulphur is driven off before decomposition of the limestone takes place, and although this found support in the experiments of Stevenson (*Journal of Gas Lighting*, 1916, Vol. CXXXIII., page 692), it is directly controverted by the researches of Campbell (*Iron & Coal Trades Review*, 1914, Vol. LXXXVIII., page 346).

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* See the results of multiple off-takes at Hubertushuette-Das Absaugen der Rohgase, by E. Jenkner, *Stahl u. Eisen*, January, 1913, page 145.

† See enquiry by U.S.A. Steel Corporation, by J. R. Campbell, *Proc. Eng. Soc. Western Penna*, 1912, vol. xxviii., page 333.

Tar.—As is the case with ammonia, the yield is favoured by a low temperature at the top of the oven, and quick removal of the gas from the chamber. Coke-oven tars vary widely in specific gravity and composition, but there is no British publication which correlates their composition with the district in which they are produced, nor with the method and temperature of recovery, such as is found in the series of analyses made by the United States Government (Department of Agriculture, 1912, Circular No. 97). It is to be supposed that in this country any differences are frequently attributed to the coal, which an impartial examination would probably more correctly trace to the treatment or process. But it should be emphasized that the tar-distiller finds his operations easier, shorter, and more profitable, the lower the percentage of carbon, and there is no doubt that, in buying he differentiates one tar from another. The maximum yield, and (from the distiller's point of view) the best composition, are not obtainable from ovens equipped with dry mains operating at high temperatures.

Hot Direct Process.—The recovery of ammonia by the hot direct process made a very strong appeal when first introduced into this country, since it required no cooling-water or condensers, and produced no effluent. At that time benzol was not recovered as a matter of course, as it is to-day, and the cooling of the gases was not necessary. The advantage over other processes is now limited to this—that somewhat less steam is required, and a smaller quantity of less noxious effluent-water is produced, since it contains no lime.

The dry main and hot circulation essential to the process yield a tar low in naphthalene, light oils, and creosote oils, and having 70 per cent. and upwards of pitch. The naphthalene remaining in the gas is dissolved (in the absence of tarry constituents) in anthracene oil. The chloride of ammonia is dissolved out of the tar by condensing for that purpose a small proportion of the liquor, and may be disposed of in one of two ways—it may be concentrated as a separate product, or (provided the formation of hydrochloric acid is negligible) it may be run into the saturator.

Semi-direct Process.—In the several variations of this process the ammonia of the condensed liquors is led indirectly through the still into the saturator, and only the ammonia remaining in the gas goes "direct." We may, therefore, accept the common method of distinguishing the process as the "semi-direct."

The pre-heat of the gas which the Koppers' process demands was originally obtained by interchange with the hot crude gas, until the inventor began to use steam pre-heaters about 1911. Originally, also, the still-gases were delivered into the crude gas before the coolers, but this procedure was very properly given up; it can be shown to add to the work of the condensers as well as to increase the weight of liquor to be distilled.

As now practised by Koppers, the gas is re-heated after being cooled and passed through tar-extractors, and the still gases added to the stream entering the saturator, at the following typical temperatures:—

	Degs. Cent.
Entering superheater	27
Leaving "	85
After addition of still vapours	81
Outlet of saturator	45

One early application of the process at Mont Cenis Colliery, Herne, Westphalia, was not successful, and led to a modification which goes by the name of that colliery. In this, the still gases are partially cooled (the condensed liquor being returned to the still) before being added to the oven-gases. Average temperatures are—

	Degs. Cent.
Gas cooled to	30
After addition of still vapours	40 to 42
After saturator	50

The thermal margin is not great, but there is no difficulty in dealing with all the water-vapour that enters the saturator with the gas.

On investigating the subject, Marr found that after the equilibrium temperature of the mixture of still-vapours and cooled gas is attained, the surplus water-vapour or supersaturation is readily removed on passing the mixed gases through any water-separator suitable for dealing with a water-fog. In his process such a separator is interposed between the place where the still-vapours are added and the saturator. The result is that, as compared with the previous processes, less water enters the acid bath, and the temperature of the outlet gas is higher, with a correspondingly higher capacity for carrying water-vapour.

	Degs. Cent.
Gas cooled to	20
At inlet of saturator	45
At outlet of "	55

In operating Marr's process, 60 to 70 per cent. of the total ammonia is found dissolved in the liquor. The free ammonia remaining in the gas reduces the proportion of free ammonia in the liquor, and correspondingly increases the proportion of fixed ammonia. Liquor of that composition is little liable to losses by evaporation.

The separate recovery of ammonium chloride and napthalene, which detract from the simplicity of the direct process, do not trouble us here, but the principal gain of the semi-direct process is the complete control of the losses which are inevitable in scrubbers, especially in hot weather, so that there is no difficulty in maintaining a 99-per-cent. recovery.

Next in importance is the reduction of the quantity of waste liquor to nearly half that of the indirect process as usually practised.

If waste liquor is used for lime mixing, the relative quantities of waste liquor to be disposed of, taking the amount obtained by the indirect process as unity, is as follows:—

Indirect process	1·00
Direct „	0·45
Semi-direct „	0·52

Benzol Rectification.—At the present time the absorbing oil is usually, although not universally, stripped of its light oil in column stills instead of in the earlier form of intermittent blow-over still. Solvays (who originated the continuous debenzolizing column) use the same method for all fractions; the light oil (65 per cent. at 120° Cent.) is passed through a similar continuous still to separate the crude benzol from the creosote carried over in the previous distillation; a third column separates the 90-per-cent. benzol from the fractions of higher boiling-point, and so on, under the same principle, until all the fractions are isolated. The operations may be followed on the accompanying diagram (Fig. 6). In each distillation the oil is fed continuously. The volume of the feed and of the liquid contained in the column is so considerable as to compensate and render negligible any variations in the temperature or quality of the oil under treatment. The appropriate temperature of the vapour having been once established, the operation proceeds continuously with very little attention, and a definite and constant fraction is recovered. As the vapours ascend the columns from tray to tray, they are subjected to liberal washing in the bubbles, and the less volatile bodies are thus scrubbed out of the vapours.

On the finished products side, the residual from any one fraction is completely vaporized in a few compartments in the lower part of the column, in order to ensure greater purity in that residual, which, after condensing, is passed on to the next fractionating column. In the smaller plants, a column and washer may be used for one fraction during part of the week, and for another fraction during the remainder. In every case the capacity of any of the columns may be increased at any time by adding more compartments and so increasing their height.

Impurities of low boiling-point, such as carbon bisulphide, are eliminated from the 90-per-cent. benzol by isolating the vapours from several of the top compartments of the column.

Conclusion.—It must be admitted that the process of coking cannot be called economically perfect until some inventor devises a more direct application of the heat necessary to distil the coal. The heat used exceeds greatly that required for decomposition. About

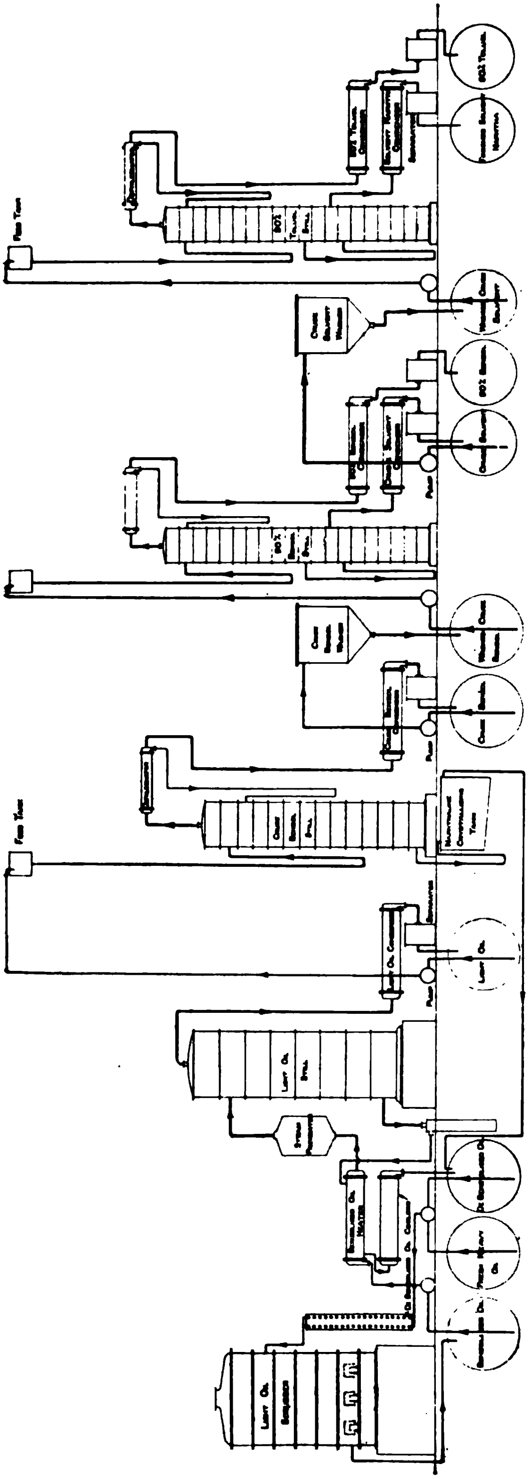

FIG. 6.—DIAGRAM OF BENZOL RECTIFICATION PLANT.

2½ million British thermal units per ton of coal treated is transmitted through firebrick—a bad conductor—and through the charge of coal or coke—still worse conductors.

We cannot be content with our limited knowledge and control of the formation and decomposition of ammonia, and must aim at the recovery of a larger proportion of the nitrogen in that or some other form, together with the sulphur now lost to us or only partly recovered in the costly manner practised since early days.

Bibliography.—The appended bibliography* deals with the principal literature relating directly to bye-product coke-oven practice. It does not embrace the standard works and publications on the allied practice of gas-works, unless they have direct bearing on coke-ovens. Work done previous to the year 1900 or of purely historical interest is not included. The preparation and washing of coal, tar-distilling, and sulphuric-acid making may be considered separate subjects, and are not dealt with in this bibliography. The subject of "Refractories" is being dealt with at the present time by various competent authorities, and no reference is made to it here. There are many valuable references in the coking section of *The Gas World*, commencing with the issue of March, 1914, but exigencies of space prevent their complete incorporation here.

Mr. J. W. Porteous (Bishop Auckland) wrote: There are one or two points in the paper which I would like to supplement. I am pleased to note that Mr. Colquhoun has dealt with the mixing of coals, a point that is greatly neglected on the majority of coking plants. A firm for which I worked during my earlier career made this a speciality, and as a result the coke produced in their beehive and bye-product coke-ovens held for many years a premier place in the North and West of England. In these days, when coal of an inferior character is being dealt with, it is more necessary than ever that Mr. Colquhoun's remarks should be seriously considered. Indifferent mixing leads not only to a lack of uniformity in the structure of the coke, but also to serious losses in the percentage yield, owing to excessive quantities of ballast being produced. The crushing of the coal is another detail to which insufficient attention is devoted. The general practice is to crush coals high or low in volatile matter to the same degree of fineness, a method that fails to bring about the rigidity and compactness in the coke which could be obtained by crushing the coals to different degrees of fineness, according to their percentages of volatile hydrocarbons; or, in other words, if a coal low in volatile matter be crushed to the same degree of fineness as a coal high in volatile matter, the area in aggregate of all the surfaces in contact, in the case of the coal with a low content of volatile matter, may be such that the combining properties of the highly volatile coal may be insufficient to bring about true coherence between the particles.

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* The publication of the bibliography has been postponed for the present owing to the paper shortage.

With regard to the most suitable moisture content, I agree with the writer of the paper that this is a matter to which too little attention is paid. If the percentage of moisture in the coal were kept within reasonable limits, there would be fewer queries regarding the cause of shortage of steam at the boilers. At the majority of coke-oven plants, water is converted into steam in the wrong place. Mr. Colquhoun has dealt very effectively with its influence on the condensation of the vapours, and there is much that he could have said also with regard to its influence on the lining of the coking chamber, and the large quantities of unnecessarily weak ammoniacal liquor resulting from the presence of high percentages of moisture. After watching its effects on various types of ovens dealing with different classes of coal, the amount of moisture should, in my opinion, never be allowed to exceed 10 per cent.; and even if present to this amount, it has a deteriorating effect upon the percentage yield of coke produced, owing to its action, when converted into steam, upon the carbon in the coke. On a plant of fifty ovens, producing, say, 1,500 tons of coke per week, it is possible, apart from other losses, to lose nearly 20 tons of coke, owing to its being converted into gaseous matter through one's neglect in keeping the moisture in the coal within reasonable limits; but the trouble does not end there: the walls of the cells of the coke are weakened, the ash-content is proportionately increased, and also the quantity of breeze produced. The destruction of fuel through this item alone has caused much misunderstanding.

As an instance of its effect upon carbonization, and its ultimate effect upon steam-raising, the late Mr. G. S. Cooper published some time ago two charts showing its effect upon two charges at the end of a 28-hour coking period. He stated that with 12 per cent. of moisture in the coal, at the end of 28 hours the temperature at a distance of 1.17 inches from the wall was 1,100° Cent., while at a distance of 6·24 inches from the wall the temperature was 1,100° Cent., and at the centre of the charge it was 1,050° Cent.; whereas with 15 per cent. of moisture in the coal the following results were obtained: at a distance of 1·17 inches from the wall, the temperature was 1,000° Cent., at a distance of 6·24 inches it was 850° Cent., and at the centre of the charge it was 800° Cent. When it is remembered that practically 520 cubic feet of gas are required to drive off each 1 per cent. of moisture in the charge above 8 per cent., it will be understood how desirable it is from a temperature and fuel standpoint for the moisture to be kept under control.

With regard to its effect upon the yield of bye-products, it is well known that, up to a certain percentage, moisture protects the ammonia compounds, and that this protection continues until 9 to 10 per cent. has been reached; but if the moisture exceeds 10 per cent., working practice proves that the amount of recoverable ammonia decreases. It has been shown by Mr. Foxwell that with a coal yielding 31 pounds of ammonium sulphate per ton of coal, with 9 per cent. of moisture present, only 27 pounds of ammonium sulphate were obtained with a moisture content of 15 per cent. Up to a certain point, as the moisture increases the tar yields increase; but when this takes place, the yields of benzol decrease, and analytical results indicate that when the moisture content exceeds 6 per cent., the benzol yield decreases by practically 4 per cent. for every 1-per-cent. increase of moisture, and over 16 per cent. of moisture causes a rapid decline in the benzol yield. With regard to the matter of compression, as Mr. Colquhoun has mentioned, by correctly stamping the coal-charges, great improvement is obtained in the coke, and also in the output of coke per oven; but I think that the fact should be remembered that where stamping is in operation this always necessitates a certain amount of moisture being present in the coal, and owing to the repressed character of the cells in the coke, brought about by stamping, the percentage yield of coke is decreased, due, of course, to the escaping steam acting more vigorously than if the coke were less dense. During the early days of stamping the following experiment was made on one battery of ovens: fourteen ovens were loaded with stamped charges and fourteen with unstamped charges; in both cases the coal contained the same amount of moisture, and was obtained from the same source. The percentage yield of coke (including breeze) which rusulted was: unstamped charges, 76·68 per cent.; stamped charges, 74·78; that is, the yield of coke was 1·9 per cent. less with stamped than with unstamped charges. Having had charge of tapered and untapered ovens for a number of years, I quite agree with all Mr. Colquhoun has to say about oven taper, and I may add that on our batteries of Semet-Solvay ovens, built at three different collieries and consisting of a total of 290 ovens, we have never experienced any difficulty in pushing the charge from the untapered ovens.

In addition to Mr. Colquhoun's remarks concerning horizontal flues, it may be stated that in the case of the ovens with horizontal flues it is possible to have a solid middle wall; and, although much has been said regarding difficulties in the radiation of heat because of the lengthening of the battery, having started numerous batteries under various circumstances I may say that where the middle wall has existed, normal conditions have been arrived at earlier and with considerably less trouble and anxiety than would have been the case in the absence of a middle wall. When it has been necessary to stop charging because of labour troubles, or to make extensive repairs to gas-mains, the presence of a middle wall has been of great benefit. On all our Semet-Solvay ovens the middle wall is 18 inches thick, and this makes it possible to put one oven "off" for repairs and re-line it completely from end to end without interfering with the adjoining ovens; whereas with the vertical-flued oven, when an oven is "laid off" for repairs, the output of five ovens is affected, unless the oven to be repaired is near one of the ends of the battery. Moreover, the horizontal-flued oven in which a middle wall is present is less influenced by high-moisture content in the coal than is the vertical-flued oven. I am familiar with two batteries of ovens, one of which has been in operation for 10 years and the other about 8½ years; both are Semet-Solvay ovens with 18-inch walls, and when only one oven has been "off" for repairs and the moisture in the coal has been kept within reasonable limits, the output of coke per battery has not been interfered with.

Mr. G. E. FOXWELL (Sheffield) wrote: I notice the author refers to the "combined water" in coal. This is presumably a slip, as, if we were entitled to say that the water evolved from coal on distillation were combined water in the same sense as that obtained in a similar manner from, say, kaolin, it would be a valuable step towards the elucidation of the problems connected with the constitution of coal. Has Mr. Colquhoun any positive evidence on this point?

With regard to the retarding influence on output, due to the taper in an oven, published figures of oven temperatures confirm the author's statement. Prof. Simmersbach has found that up to the end of the period in which the moisture is being evaporated, the temperature of the coal at points equidistant from each oven wall at the narrow and wide ends of the oven is the same. After this, however, the temperature at the narrow end rapidly increased, and by the time it approached its maximum the temperature at a particular point was 280° Cent. above that of a similar point at the wider end. At the same time, I fear that the wear and tear on the oven walls would be too great to justify the building of untapered ovens. This would be especially noticeable with regard to bricks inclined to "spall," or which had been attacked by salt.

I cannot subscribe to Mr. Colquhoun's statement that there is a reversion of opinion in favour of horizontal-flued ovens. In a recent issue of the American *Iron Age*,* details of the coke-oven plants in the United States were given. From this and other information I find that the plants now under construction in the United States are as follows:—

Type of oven.	Number of ovens.	Arrangement of flues.
Koppers	2,677	Vertical.
Semet-Solvay	324	Horizontal.
Wilputte	85	Vertical.

I regret that at this short notice I cannot obtain similar information with regard to coke-oven plants in this country.

The author passes severe strictures on the difficulty of regulating combustion in vertical-flued ovens. I believe that in the case of most ovens he is quite correct, but in the case of one type—the Koppers oven—his criticism is not warranted. In this type there are four different opportunities and devices for regulating the draught: (1) the chimney damper, which regulates the heat for a whole battery; (2) and (3) the air-inlet and the waste-gas outlet, which regulate the combustion for each complete set of flues; and (4) at the top of each individual flue a firebrick damper is placed, which serves to regulate the combustion of each flame. From my personal experience I know that it is possible so to regulate the combustion as to maintain an absolutely even temperature throughout the oven wall, with a waste-gas containing, say, 2 to 3 per cent. of oxygen. This I find to be the lowest figure consistent with the absence of unburnt gas.

The author is on very debatable ground when he states that the distribution of heat in horizontal-flued ovens is uniform. On purely theoretical grounds, it seems impossible to have a flame 32 feet long which can heat a given area equally at any point along its length. It must inevitably happen that the few feet along which combustion commences is a zone of much more intense combustion than that at the other end of the flue. It cannot be wholly true to say that the products of combustion carry the heat to the cooler end and so equalize the temperature, for these products are required to give up a notable proportion of their heat as they pass along the flue in order to carbonize the coal. The whole question is very debatable, and has apparently never been adequately explained by an absolutely unbiassed authority utilizing the results of experiments.

Another controversial matter is that which concerns the formation of ammonia. The author states that "the thermal decomposition of the gases which are evolved is inappreciable below 870° to 900° Cent., and this fixes the temperature of operation at the top of the oven-chamber." This is surely not quite accurate since if coal-gas, containing no tar, is passed through a tube containing firebrick at 500°-600° Cent., a plentiful deposit of carbon is formed. Tar consists of bodies still more easily decomposable. Moreover, the products obtained by distilling coal at lower temperatures are of a paraffinoid nature, and these bodies are converted into aromatic compounds at a higher temperature. As regards the tar, the temperature of 900° Cent. may be considered as that below which the tar would be contaminated with paraffin, and above which too much decomposition occurs.

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* April 4th, 1918, page 857.

The thermal decomposition of ammonia takes place at quite a low temperature, but may be partly prevented by adding excess of nitrogen or hydrogen, in accordance with the law of mass action. The same effect, although not so marked, is observable on dilution with other gases.

Undoubtedly decomposition of ammonia takes place at 900° Cent. We must not, however, overlook the temperature of formation of ammonia from coal. The amount increases with the temperature, as *vide* the formation of ammonia by direct combination of its elements on passing through the electric arc. The time spent by any given molecule of ammonia in the coke-oven is, however, relatively so much longer than that spent by a molecule in the electric arc that decomposition robs us of a considerable portion of the ammonia. The optimum temperature of 900° Cent. is that at which the two reactions so balance as to give the highest yield. I cannot resist the conclusion that higher yields of ammonia would be obtained by drawing the gases out of the coke-oven rapidly by high suctions, and at the same time using higher temperatures.

I can bear out all Mr. Colquhoun's statements with regard to the hot direct process.

Mr. J. MARR (Sheffield) wrote: It would be of interest to coke-oven builders to know whether our Government, even after the war, would permit them to follow the American practice of coking in 16 hours, if it involves a loss of 20 per cent. on tar and benzol and 10 per cent. on sulphate. A ruling on this point would indicate in what direction developments should proceed.

I agree with the author's statement that "regenerative ovens *per se* are not more economical than waste-heat ovens," but the surplus-energy balances, as stated under headings 1, 2, and 3, do not, in my opinion, bring out this point very clearly. The apparent balance in favour of the regenerative oven is entirely due to the higher efficiency of gas-engines compared with steam-turbines. A true comparison can only be made when the surplus energy for each case is stated in similar units. If we select surplus gas or its equivalent in steam per ton of dry coal, we have surplus energy for:—

Case 1.—5,500 cubic feet of gas.

Case 2.—(*A*) 7,000 cubic feet of gas (*i.e.*, the equivalent of 2,000 pounds of steam raised in Lancashire boilers).

,, (*B*) 5,200 cubic feet of gas (*i.e.*, the equivalent of 2,000 pounds of steam raised in Bonecourt boilers).

Case 3.—(*A*) 7,100 cubic feet of gas (*i.e.*, the equivalent of 1,400 pounds of steam raised in Lancashire boilers, plus 2,200 cubic feet of surplus gas).

,, (*B*) 5,840 cubic feet of gas (*i.e.*, the equivalent of 1,400 pounds of steam raised in Bonecourt boilers, plus 2,200 cubic feet of surplus gas).

From these figures it would seem that the waste-heat oven *per se* is at least equal in economy to the regenerative oven.

This is true for horizontal-flued ovens when the excess air is admitted into the top flue. Under such conditions, the excess air in the products of combustion leaving the ovens may be reduced to 5 per cent. in the waste-heat ovens and 80 per cent. in the regenerative ovens (in practice these figures have been known to be lower).

A study of coke-oven gas with a calorific valve of 450 British thermal units per cubic foot will show the following temperatures of combustion, for gas at 0° Cent., with varying proportions of excess air of different temperatures:—

No.		Excess air. Per cent.	Temperature of air Degrees Cent	Temperature of combustion. Degrees Cent.
1	... ...	5	0	1,840
2	... ...	25	0	1,680
3	... ...	80	900	1,880
4	... ...	130	900	1,700

Nos. 1 and 3 are permissible in horizontal-flued ovens, as explained above. Nos. 2 and 4 are of necessity practised in vertical-flued ovens in order to keep below the fusing-point of the brickwork, which is about 1,700° Cent. No. 2 is for waste-heat and No. 4 for regenerative ovens.

Assuming that in all four cases the products of combustion pass up the stack at 300° Cent., it can be shown that the amount of heat lost per molecular volume of gas burned is for case (1), 11·3 calories; case (2), 13·0 calories; case (3), 17·7 calories; and case (4), 21·9 calories.

Taking the amount of gas burned in the flues as 78 per cent. in the waste-heat oven and 50 per cent. in the regenerative oven, we can compare the losses in the stack thus:—

Waste-heat horizontal flues, 0·78 × 11·3 = 8·82 calories.
,, vertical ,, 0·78 × 13 = 10·15 ,,
Regenerative horizontal ,, 0·50 × 17·7 = 8·85 ,,
,, vertical ,, 0·50 × 21·9 = 10·95 ,,

From these figures it will readily be realized that the losses in the stack in waste-heat and regenerative ovens are about equal, and that the losses in either type of horizontal-flued ovens are appreciably less than in vertical-flued ovens.

Mr. Colquhoun remarks that multiple ascension pipes would increase the yield of ammonia, and I suggest that their adoption would prove advantageous in other directions. For instance, the increased pressure common to all ovens in the early period of coking would be reduced, and during the later period, when only one ascension pipe would be required, the others could be cleaned without interruption to the working of the oven.

An investigation by the Otto Company in America showed that 50 per cent. of the total gas was given off in the first 40 per cent. of the coking time. With a coking period of 30 hours, 50 per cent. of the gas would leave the oven in the first 12 hours and 50 per cent. in the last 18 hours.

Assuming that a coal containing 15 per cent. total moisture is used, and that the moisture is all driven off in the first 12 hours, the volume of gas and steam leaving the oven during that period at, say, 750° Cent. is twice the volume of gas leaving the oven at, say, 850° Cent. during the remaining period. In other words, the average volume per hour passing through the ascension pipes for the first 12 hours is three times greater than in the last 18 hours; hence the reason for the increased pressures when an oven is newly charged.

It will be of interest to remark here that the average heat transfer per hour through the oven walls in the first period is about six-and-a-half times that of the second period.

Mr. **M. W. Blyth** (Thorncliffe Iron Works) wrote: One advantage of horizontal flues appeals to me very strongly, namely, the whole of each flue is exposed to view, and by means of an optical pyrometer the temperatures in each flue and in each part of the flue can be determined accurately. Further, in the Semet-Solvay oven the temperature in each of these flues can be adjusted and varied with ease. It is possible so to adjust the zones of heat that there is a gradual decrease from the bottom to the top of the oven. This should lead, at least theoretically, to less degradation of the bye-products. In practice, the results are not obviously better than with vertical flues.

Mr. Colquhoun states that there is uniform distribution of heat, a statement that certainly requires modification. I should prefer to say that the distribution of heat is sufficiently uniform. In the Semet-Solvay flue there is a distinct hot zone, in each, a few feet from the point of entry of the air and gas, and there are also differences of temperature along the length of the flue walls. For example, the following observations were made on the wall of one of the fourth flues (counting from the top):—

1,085°, 1,100°, 1,130°, and 1,160° Cent., and in the hot zone, 1,220° Cent.

It must be remembered that differences of heat, within limits, are not so important as are variations, and in vertical-flued ovens variations of heat are bound to be considerable. In the Koppers regenerator oven it is impossible to observe the walls of the vertical flues with the optical pyrometer; all that can be seen is the top horizontal flue and the bottom air-block. The following observations were made on the bottom air-block, which corresponds to the hot zone in the Semet-Solvay oven:—

	Degrees Cent.
At the moment of "changing over"	1,500
After 10 minutes	1,410
" 20 "	1,370
" 30 "	1,370

In no flue, vertical or horizontal, is the distribution of heat perfect, and much more could be done in this direction than is the case at present, by action based on the accurate measurement of flue temperatures. The whole success of the operation of coking, whether the aim be gas or bye-products, or a rapid output of coke, depends on maintaining proper flue temperatures. At present this important matter is left largely to the eye-judgment of the gas-regulator. Ovens should be so constructed that all parts of the flue walls can be optically inspected, and the temperature accurately determined.

Mr. Colquhoun states that one person only is necessary for working the feed-table and conveyor. At both of the 12-ton batteries referred to in his paper two persons are employed on this work alone. We find that the time taken to stamp a 12-ton charge is 32 minutes, and not 24 as stated by the author, and in order to do even this we have had to modify the stamping plant originally supplied.

With regard to the 12-ton oven, so many factors have to be considered that personally I hesitate to express an opinion either for or against it. Briefly, the points upon which I am not satisfied are the following:—(1) Does the high narrow cake lead to more broken cakes? (2) Do the ends of these cakes always have to be tapered off? (3) Is there some degradation of bye-products, owing to the further travel of the gases through hot coke? (4) Is a larger coke-bench required, or are special arrangements necessary for dealing with the coke in order to avoid excessive moisture? Even if these queries be answered in the least favourable way, it does not follow that the 12-ton oven, under future labour conditions, will be an unattractive proposition. Possibly Mr. Colquhoun, with his wide experience, can enlighten the members on some of these points, as the question of the future size of ovens is of the first importance.

Mr. A. C. MIDDLETON (Sheffield) wrote: Having had charge of a horizontal-flued coking plant for over twelve years, one cannot be accused of being prejudiced in favour of vertical-flued ovens. Although horizontal-flued ovens have much to recommend them, there is one great advantage which the vertical-flued regenerative oven possesses over the horizontal-flued oven, namely, the quantity of spare gas which it produces.

Calculations are given in Mr. Colquhoun's paper showing the relative values of waste-heat and spare gas for power-raising purposes, but one does not notice any reference to the use of this spare gas for lighting purposes. Many coking plants are situated near large towns, and those responsible for the gas undertakings of these towns would be only too glad to obtain this gas to supplement their own supply, and pay a price much higher than its value for power-producing purposes.

For public supply, a high-quality gas is needed (say, 500 British thermal units); for power production, low-grade gas can be utilized. For the production of the high-grade gas, good gas-coal or coking coals are necessary; whereas for the production of power gas, inferior fuel can be used which could not take the place of gas-coal, and which is often quite unsaleable. Would it not be a more profitable proposition, instead of using good gas for power purposes, for owners of coking plants to dispose of their spare coke-oven gas for lighting purposes, and utilize only the most inferior fuel to make producer-gas for generating power?

This practice of supplying lighting-gas has been in vogue for many years in America and Germany, and is now engaging much attention in England. During the past year or two, the whole of the lighting-gas used in Middlesbrough has been derived from neighbouring coke-ovens. By this practice, a considerable national economy is effected both in reducing the amount of high-class gas-coal used and in utilizing otherwise unsaleable inferior coal for producing power.

Apart altogether from the relative merits of either horizontal-flued or vertical-flued ovens, the question of whether it is an advantage or otherwise to compress the coal is a thorny one. Where the coal is only a poor coking coal, great advantage is gained by compressing, but it is very doubtful whether there is much gain when using a good coking coal. It is a fact that at many coking plants compressors have been discarded, and hand-charging has been reverted to. With the new charging lorries and mechanical levellers, it is a very much quicker operation than stamping cakes. I have heard on excellent authority of an instance where seven ovens were charged and levelled in one hour. This is much quicker than the making of cakes. With mechanical levellers it is possible to get the charge levelled quite as well as with compressed charges.

Doubtless the yield of coke per oven is increased by compressing, and with the present-day method of trade unions regulating the output of a plant at so many ovens per shift, this is an advantage; but the writer is convinced that this method of regulating the output of a plant will not last long. The workmen will surely notice the tendency to increase the size of ovens, and will then insist on a smaller number of ovens per shift, or will regulate their work on a tonnage basis.

Mr. C. H. Merivale (Leeds): How low may one safely take the moisture, without losing the cloud of moisture that apparently conserves the nitrogen as it is given off from the oven? Some of the older colliery companies are considering the question of coking all the coal coming from their pits, and the point as to how low a percentage of moisture one dare go will become important. Dare we go as low as, say, 5 or 6 per cent.? Another point is the enormous value of the gas that many of us are not making the most of. There is no mention in the paper of selling gas for illuminating purposes, or of dual mains. We are told that in some parts of the country people are putting up dual mains, taking off the richer gas, and selling it, possibly, for town-lighting. I am at present selling gas for town-lighting, and am putting up dual mains in an endeavour to improve the quality. It seems reasonable to suppose that this might lead to our being able to use higher suctions, as mentioned by Mr. Foxwell, thereby possibly increasing the yield of ammonia. Owing to the fact that we have had the dual main, we can afford the high suction on the oven, and the low-grade gas can either be burnt under the ovens or enriched and disposed of in other ways.

Mr. Roslyn Holiday (Ackton Hall): Many plants furnish figures connected with the weights of material dealt with, but one experiences considerable difficulty in getting at the true weights, and this of course affects the accuracy, and therefore the value, of the figures considerably. Mr. Colquhoun suggests a continuous conveyor-band, but the trouble is that, as there is a certain percentage of moisture in the coal, the coal very often adheres to the belt, and, although machines may have been balanced perfectly well at first, after a time the belt becomes coated with fine coal, which is weighed over and over again, thus affecting adversely the accuracy of the weighing process. On the other hand, we have tried allowing this coal to remain on, and balancing the belt while it is dirty; but the coal breaks off in cakes, and thus the accuracy of the weighing operation is again destroyed. The continuous weighing-machine would be very good if there were some way of continually keeping the readings accurate without the necessity of having somebody to clean the machine all the time.

The PRESIDENT (Mr. W. D. Lloyd): I feel that papers of this kind are of great value at the present time, because in the past we have perhaps been too dependent, so far as coking is concerned, on foreign experts, more particularly German coke-oven engineers, and an interchange of ideas between English engineers will certainly lead to our being more independent of outsiders.

Mr. W. COLQUHOUN (Sheffield), in reply, said: I do not think the question of how low with advantage one may go in the moisture content of coal has ever been raised before. The greatest trouble is to get it low enough, and the only thing which prevents too low a moisture content is that the coal would not be efficiently compressed. In America, they have practically no washed coal. It is all dealt with in a dry state, and therefore the moisture content in American practice is extremely low, and the quality of the coke is excellent. As far as I understand Mr. Merivale's question, I consider that the results obtained in American practice are a sufficient answer. The question of dual mains, and the use of surplus gas for purposes other than those to which I have referred, is a very large one. I had written some paragraphs on it, but afterwards omitted them in order to keep the paper within bounds. In regard to the weighing of coal on bands, whatever error there may be in weighing, it must be constant, and if, for instance, there is wet coal sticking on the band, it is constant to all intents and purposes. There will be, of course, momentary errors arising out of flakes dropping off the band; but, taking year in and year out, I would say that the band has at least a constant error, and an allowance in respect of this gives a result considerably more accurate than the rough-and-ready method which is at present used. Moisture must, of course, be allowed for: the varying moisture of the coal being delivered on to the band must be determined. This can be checked by taking a proportion of the coal off the belt once an hour, and mixing and quartering the sample in order to arrive at an average moisture content for the weight dealt with during the day. I propose at a suitable opportunity to consider the suggestions made in the written contributions to the discussion more fully than is possible to-day, and to reply at a future meeting.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD AT THE ROYAL TECHNICAL COLLEGE, GLASGOW, DECEMBER 7TH, 1918.

MR. D. M. MOWAT, PRESIDENT, IN THE CHAIR.

DISCUSSION OF MR. STEWART CHAMBERS'S PAPER ON "THE REPAIR OF A CIRCULAR SHAFT OF SMALL DIAMETER."*

The PRESIDENT (Mr. D. M. Mowat): This particular type of paper is one we all want to hear read and discussed. No one knows when he may have to face a similar task to that described by Mr. Chambers, so that his description of the steps taken to overcome the difficulty will be very helpful.

Mr. STEWART CHAMBERS (Philpstoun), in reply, said: Mr. Mowat thought that the tube should have been bigger in diameter. That, I may point out, was one of our chief difficulties. The shaft was so badly twisted that a tube anything like the size of the shaft could not have been got down. It would not have been possible to put down a 5- or 6-foot diameter tube. It was suggested by Mr. Kirkby that something cheaper than old grease barrels and boxes might have been used, such as stones; but it was only after our supply of stones had run down that we thought of using grease barrels and boxes.

The discussion of the paper was closed.

DISCUSSION OF MR. JAMES A. YEADON'S PAPER ON "THE ECONOMY OF BRIQUETTING SMALL COAL."†

Mr. R. W. DRON (Glasgow): One of the points essentially connected with the briquetting of small coal is the treatment of wet small coal. This was seriously considered at Manor Powis Colliery, and Mr. Yeadon is erecting a special contrivance of his own for drying the wet small coal at this colliery. I understand that he was the first to put up plants of that kind in this country, and that he has been responsible for a considerable number on the Continent. The wet coal passes on to a revolving drying plate, and at the same time a fan causes a draught of hot air to pass over the small coal. By this process the moisture in the small coal will be reduced to the point necessary for the briquetting process. In addition to that, it is necessary to give a certain time to the process of drying preliminary to the treatment referred to. Bunkers are being erected at Manor Powis Colliery so that the small coal can rest in them for a certain number of hours. When Mr. Yeadon replies to the discussion, he might give some of his experiences on the Continent in the methods of drying the small coal, as this is of the highest importance.

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., page 203; and 1918-1919, vol. lvi., page 30.

† *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 31.

The **President** (Mr. D. M. Mowat): Do you know whether Mr. Yeadon intends to dry the coal below its normal condition, or just to remove the moisture that is put into it by the washer?

Mr. **R. W. Dron**: There is no intention of drying the coal below its normal conditions. There is a class of small coal which it is very difficult to wash. This is coal which breaks down into dust. When the dust is put into the washer, it becomes sludge, and is very difficult to recover. It would be worthy of investigation to discover some process of dry-cleaning for recovering small coal of this class.

Mr. **John Gibson** (Kilmarnock): The question naturally arises: does briquetting pay? The answer may possibly be found in the fact that briquetting has been carried on on a small scale in Scotland in the past. Mr. Yeadon has, however, made out a good case in his paper, which deserves our most earnest consideration. Duff, if it is clean, is simply a very small lump of coal, and it seems to me that the very first question that has got to be considered here is the one of washing. I know of one case where the natural ash from the coal might be taken as 8 per cent. After washing, while the manipulation of the washer had accomplished its main purpose, the ash in the duff actually increased to 30 per cent. I suppose many of the members of the Institute will have seen the very fine duff or culm which is used in particularly large quantities in some districts of Ireland and Wales. This fine coal-dust is used wet, but it is intimately mixed with about 5 or 10 per cent. of ordinary yellow clay. I have seen this material burning in open grates, and I have known the fires to burn continuously for 24 hours and give off large quantities of heat all that time. One of the main factors in connexion with the briquetting problem is the necessity for getting a cheap binding material. Pitch is the ordinary binding material used, and clay and cement have been tried, but it appears to me that the use of a cheap binding element, with hydraulic pressure to produce the ovoid briquettes, and burning the briquettes in boiler fires, should offer a solution of the problem.

Mr. C. C. Reid (Cowdenbeath): I went into the question of briquetting some time ago, and had some information supplied to me from America, where briquetting is very largely carried out. Mr. Gibson says the reason why briquetting in Scotland has been a failure so far is because it has not paid. May it not, however, be due to the fact that it has not as yet been sufficiently tried in this country. I am told, for example, that there is a great deal in the way the material is masticated. In America, where briquetting is being carried on on a very large scale, and where there are many large plants, mastication and drying are regarded as extremely important. If it pays America to go in for briquetting—and we know what America could produce coal at in pre-war days—surely a case has been made out for briquetting in Scotland? In the correspondence I had from America I was informed that if the free-tar content was brought down to about 5 or 6 per cent. and the binding material was pitch, they would guarantee that the calorific value of the "ovoid" briquette would be as good as the round coal itself. I do not know how far that statement may be true, but there is no doubt that America is strongly in favour of briquetting. Mr. Yeadon states that if the plant is well-handled, it can be made to pay its own initial cost inside two years. If we are going to get down to anything like the low prices for duff in pre-war days, there is a good margin to work upon between the price of duff and the cost of round coal, whereby a reasonable profit could be made out of briquetting. I am satisfied that this question of the treatment of duff is one well worthy the consideration of the whole mining world, and I should like to hear definite and detailed results from Mr. Dron as to the Manor Powis experiment.

The President: I have no very pronounced views as to the profitableness or otherwise of briquetting. I do think, however, that there is much to be said in favour of the remarks made by Mr. Reid. If the coal is of such a nature as to make suitable briquettes for boiler or house fires, something might be done in the way suggested by Mr. Yeadon. I further believe there is something in what Mr. Reid has said about crushing the material thoroughly down so as to provide a more homogeneous briquette.

The further discussion of the paper was adjourned.

THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION.

By F. W. HARDWICK, M.A.

The Engineering Training Organization has been formed to serve as a central organization* for improvement in and better co-ordination of engineering training. Three objects† in particular are mentioned on which the proposed central organization might usefully concentrate its attention, namely:—

> "The first is the co-ordination of engineering training, including the fostering of apprenticeship as a national institution, and the consideration of means by which the works period of an engineering pupilage may be increased in efficiency, and a wider appreciation secured for the value in industry of university rank.
>
> "The second is the maintenance of a Central Bureau, where parents and educationalists can obtain accurate and comprehensive information relating to the engineering industry, and the proper course to pursue on behalf of boys who are desirous of making engineering their profession.
>
> "The third is the promotion of scholarships, or other equivalent means by which the best talent may be enabled to rise to its proper level under the stimulus of educational opportunity."

The second of these objects will be considered first, partly because it seems necessary to have a clear and definite view of what is actually being done in education relating to coal-mining before the first of the objects named is taken into detailed consideration, and partly because it is a subject in which I have always felt personally interested.

The work of a central bureau formed for the purpose of furnishing information respecting the training of young men who propose to become engineers must depend on the information given to that bureau by the various branches of the engineering profession. Hitherto The Institution of Mining Engineers has issued no instruction on this subject, although several very interesting papers‡ have been contributed to the *Transactions*; whilst the discussions on these papers have revealed a variety of opinions, and have shown that a large amount of interest is taken in the matter. Schemes of education for young men who are to be trained in coal-mining are contained in some of these papers, in calendars and other official publications of Universities, Colleges, and Technical Schools, and in corresponding publications of education committees in coal-mining districts; but hitherto no attempt has been made to collect this information, to digest it, and to present it in such a way that anyone who desires to profit by it can do so without a considerable amount of labour.

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* "The Engineering Training Organization," Nos. 5 and 6.

† "Engineering Training," No. 2, par. 4.

‡ A list of some of these papers is appended to this paper.

The question may be asked whether such action is at all necessary? All members are acquainted with the various ways in which entry into the profession may be obtained, and in case of doubt on any point they know where to apply for information. It must, however, be remembered that this knowledge is not available to persons outside the mining profession, and can only be obtained by them with some difficulty. The choice of a profession for their sons is not an easy task for some parents, who do not know where to apply for the information necessary to enable them to decide on this important point. I used to think that a guide to the professions might be compiled, giving an outline of the training required for each profession, and the sources from which fuller information might be derived: fortunately the formation of the Engineering Training Organization seems likely to supply this want as far as engineering is concerned.

It may possibly be due to this difficulty of obtaining information that in some cases the choice of a boy's career is postponed until he is about to leave school; it is then too late to rectify any omissions in the latter part of his school training, and either the boy must be put to work partially equipped, or time must be spent on a subject, or subjects, in which he might have had instruction at school.

If professions and industries give some clear and definite indication as to what is required, then the schools can make their arrangements in accordance with them. In this way there would be a better co-ordination of work. The change from school to the University or College, or to professional training, should be accomplished as smoothly as possible, and this can be done if the professions themselves give some guidance as to the courses available. Apart from the reason just given, the opportunity is a favourable one for the Institution to take stock of what has been, and is being, done in educational matters relating to coal-mining for its own information. If a report on the facilities at present existing for such education could be drawn up, giving a brief outline of the subject with references to the sources from which fuller information can be obtained, it would be of advantage not only to those mentioned in the previous paragraphs, but also to the members of the Institution. Such a survey of what has been accomplished would be of assistance to those who are preparing new schemes, and might obviate unnecessary labour and overlapping.

The arrangement of a scheme of education in coal-mining differs from similar work in most other branches of engineering in that such a scheme must conform to the requirements of the Coal Mines Act, 1911, respecting the First-Class Certificate of Competency and the Surveyors' Certificate, and to the rules laid down under that Act by the Board for Mining Examinations. These requirements affect both the period and nature of the practical training, as well as the subjects which must be studied by candidates. These are, of course, minimum requirements, but whatever else may be added by professional opinion, care must be taken that the legal requirements are not infringed.

Any general statement, therefore, relating to the course to be pursued by a student in coal-mining should contain a clear account of the regulations on the subject contained in the Coal Mines Act, 1911, and in the rules of the Board for Mining Examinations. The statement should explain any technical points which would not be understood by a person not connected with the mining profession, and those who are personally interested should be referred to the Home Office on matters of detail or doubt, and as to changes in the regulations.

The regulations for the Surveyors' Certificate should also be given, with suggestions as to the best form of training for this certificate. On this point the Institution might give some guidance as to the advisability of a mining student preparing for both the First-Class Certificate of Competency and the Surveyors' Certificate. Mr. R. W. Dron, in his paper on "The Training of Mining Engineers,"[*] has already mentioned this point, and it is important to know what is the general feeling on the subject, remembering that a student who has obtained his First-Class Certificate of Competency must spend a further two years in working for the Surveyors' Certificate.

It is not proposed to enter into the various points connected with the school training of a boy who intends to enter the engineering profession. The subject has been fully dealt with in a Report[†] of the Institution of Civil Engineers and in "Natural Science in Education,"[‡] and to the conclusions contained in these reports I have nothing to add. I consider that the subjects of mathematics, mechanics, physics, and chemistry should be taken before they leave school by all boys who propose to become engineers.

The training of students who propose to take the First-Class

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[*] *Trans. Inst. M. E.*, 1914-1915, vol. xlix., page 187.

[†] "Report of the Committee [of the Institution of Civil Engineers] appointed on 24 November, 1903, to Consider and Report to the Council upon the Subject of the Best Methods of Education and Training for all Classes of Engineers," William Clowes & Sons, Ltd., 31, Haymarket, S.W.

[‡] "The Report of the Committee on the Position of Natural Science in the Educational System of Great Britain," H.M. Stationery Office.

Certificate of Competency may be conducted on one of three lines, namely: —

(1) Attendance at an " approved " institution, obtaining an " approved " degree or diploma, and serving as an articled pupil at a colliery for a period of not less than three years.

(2) As an articled pupil at a colliery for not less than five years.

(3) Practical experience (as defined in the rules of the Board for Mining Examinations) for not less than five years at a colliery.

Although these various kinds of training present marked differences, yet to some extent one class overlaps the other. In all of them attendance at courses of technical instruction is possible; in the first it forms a necessary part of the training.

A study of the " approved " courses would be of interest, and would show what is being done at the present time. Some years ago, in the discussion on a paper by Prof. R. A. S. Redmayne* on " The Mining Department of the University of Birmingham," I contributed a comparative table† of the courses at the various institutions which were at that time " approved." If similar information were to be presented at the present time, in an improved form, it would show the lines on which various institutions have developed their courses, and would indicate the preparatory training required by each institution for students who proposed to attend. Divergent as are the views which have been expressed on the subject of the best training for coal-mining students, it will probably be found that there are courses already in existence to suit every variety of opinion. There are about fifteen institutions on the " approved " list, and some of these have both degree and diploma courses. A detailed account of each course does not seem to be necessary; information is required chiefly under these heads:—

(1) Regulations as to entrance; in the case of degree students, by matriculation, or by passing an examination which is recognized by the particular institution as equivalent to matriculation; in the case of diploma students, whether there is any entrance examination, and, if so, in what subjects.

(2) Length of course.

(3) General outline of course.

(4) Academic distinction awarded.

(5) Whether there are any vacation courses which students are expected to attend.

(6) Whether the regulations provide for practical work during the vacations.

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* Now Sir Richard Redmayne, K.C.B., H.M. Chief Inspector of Mines.

† *Trans. Inst. M. E.*, 1904-1905, vol. xxviii., page 483.

(7) Whether students are trained in coal-mining only, or whether instruction is given in other branches of mining.

As the regulations concerning these courses may be changed in the future, it should be explained that the information given refers only to existing conditions.

A recommendation has been made, especially in recent years, that after leaving school, and before entering a University or College, a boy should spend some time in practical work. A year is generally mentioned, but nine months has also been suggested. The object of this is to give the boy an insight into his professional work, and to bring him into touch with it at an earlier age than would otherwise be the case. This proposition requires very careful consideration, and it would be interesting to know whether the result has been satisfactory in any cases in which it has been put into practice. It may be questioned whether the beneficial effect of the practical experience so acquired is not set off by a loss of knowledge already acquired, which would have to be learned again when the student enters on his applied-science training. This, however, is a point which can only be decided by experience.

On this question it would be interesting to know to what extent intermittent periods of practical work at a colliery are allowed to count towards the minimum period of three years required by the Coal Mines Act for this class of student.

The training of the articled pupil has next to be considered—that is, the student who enters into articles for five years, as distinct from those students who take a degree or diploma and become articled subsequently.

Some of the "approved" courses are probably so arranged that they can be taken by pupils while serving their articles. A course of this kind was mentioned by Mr. G. Blake Walker* in the discussion on Mr. R. W. Dron's paper on "The Training of Mining Engineers," and enquiry would, no doubt, reveal the existence of other similar courses. The course appears to be arranged on the "sandwich" system—that is, six months at the university and six months at the colliery—a system which has already been in practice for some years for students in mechanical engineering.

Where no arrangements are made for articled pupils to attend a course of instruction of this kind, they can gain some knowledge of the necessary science and applied-science subjects by attendance in their spare time at such classes as may be within their reach established by a University or College, or by the local education authority. Probably in every district there exist facilities of this kind, in most cases organized courses held either in the evening or on Saturday afternoons, and these are available also for those who obtain the Certificate of Competency in the third way indicated previously—that is, by practical work in the mine. The number of these courses is so considerable that it would be impossible to refer to them in detail, but some indication might be given respecting the work which is being done generally.

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* *Trans. Inst. M. E.*, 1914-1915, vol. xlix., page 208.

Among the points mentioned in the first of the objects of the Engineering Training Organization is "The Fostering of Apprenticeship as a National Institution." This is explained more fully in "The Engineering Pupilage and the Engineering Trade Apprenticeship," by Mr. Algernon Berriman, O.B.E., to which reference should be made. As the terms "articled pupil" and "apprentice" are in some cases used as though they were identical, it may be as well to state that in Mr. Berriman's paper the difference is defined thus—the "articled pupil" goes into the works in order to gain knowledge of the way in which the work in various departments is carried on, and to obtain an insight into the details of the organization; he does not do so in order to acquire manual skill. The object of the "apprentice," on the other hand, is to acquire such knowledge as will make him a skilful workman, and the scheme outlined in Mr. Berriman's paper is drawn up with the idea of enabling the apprentice to do this, while at the same time careful attention would be paid to his technical education at a school or college, and opportunities of gaining experience in various departments of the works would be given to those apprentices who showed most promise. This, however, is not the whole of the scheme, since those apprentices who showed the greatest promise would be given the opportunity of carrying their training still further. In this way young men of talent would receive an excellent technical education, while those who were less gifted would obtain a sound training that would enable them to do suitable work in their profession.

It is a matter for consideration how far these suggestions can be applied to coal-mining, and for enquiry as to whether anything has been done in this direction.

Schemes which appear to be somewhat similar have already been mentioned in the *Transactions* by Mr. G. Blake Walker* and by Prof. W. Ripper,† as being either in contemplation or in operation in the neighbourhood of Sheffield; and similar schemes in other parts of the country were alluded to by Dr. Henry

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* *Trans. Inst. M. E.*, 1917-1918, vol. liv., page 482.

† "University Education in Relation to Mining Engineering," by William Ripper, C.H., D.Eng., D.Sc., M.Inst.C.E., *Trans. Inst. M. E.* 1917-1918, vol. liv., page 287.

Briggs* and by Prof. George Knox† in the discussion on Mr. G. L. Kerr's paper on "The Higher Training of Colliery Managers."‡

Details of such schemes, and information as to the experience which has been gained in working them, would be of great interest, and would be useful to those who contemplate the idea of attempting something similar.

The other points which are dealt with in the programme of the Engineering Training Organization may be left for future consideration when they have been more fully developed.

Lack of time has not allowed me to go more fully into the subject of the paper, and to present more clearly the points which I wish to make. My present work has nothing to do with mining education, and consequently I have lost touch with the latest developments; but perhaps for this reason I am better able to appreciate the difficulty which persons outside the profession must experience if they desire to obtain information on the subject of the training of students in coal-mining.

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* *Trans. Inst. M. E.*, 1917-1918, vol. liv., page 152.

† *Ibid*, page 143.

‡ Ibid, 1916-1917, vol. liii., page 182.

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"Notes on the Education (Scotland) Bill," by William Jarvie, 1917-1918, vol. lv., page 149; discussion, vol. lv., pages 154, 203.

Mr. R. W. Dron (Glasgow): As there has already been considerable discussion on the subject of the training of men who aspire to become colliery managers, I would like to direct some attention to the training that should be given to men who desire to hold positions above the manager and, at the other end, to the men who will do the actual work of mining the coal. With regard to the first class, one of the essential requirements of the mining industry in the future is to secure the best brains of the rising generation, trained by the highest scientific education. In order to draw such a class of men into the industry, inducements should be given whereby a youth when choosing a profession would know that in mining he could look forward with some confidence to an adequate reward for the time and expense of his education—a reward similar to that which may be obtained in other professions such as medicine, law, or civil engineering. One suggestion might be to institute a higher certificate than that issued to the colliery manager—a certificate which could only be obtained after a thorough and wide scientific education. This certificate might be termed an "agent's certificate." With regard to the other class, in the mechanical engineering trade an apprentice is trained primarily to become an efficient journeyman. In coal-mining little or no attention is paid to the apprenticeship of the men who are to become journeymen colliers or underground workers. It would add greatly to the efficiency of coal-mining if greater attention were paid to this point. If a lad when he enters the pit is treated as an apprentice who is there to acquire the knowledge of handicraft necessary to qualify him as a journeyman collier, the result would be a great increase in the future efficiency of that youth. Such training would all tend to greater safety, to better wages for the men, and to increased output per man employed.

The further discussion of the paper was adjourned.

COOLING OF ELECTRIC MOTORS, WITH SPECIAL REFERENCE TO TOTALLY-ENCLOSED MACHINES.

By P. A. MOSSAY.

The progress in dynamo design during the last few years is gradually reducing the problem of a further advance to the solution of a more and more complicated thermal problem. In the early days the size of dynamos and motors was limited by considerations of sparking or regulation; in comparison with the present machines, the overall dimensions were much larger, and it seldom mattered whether the cooling-surface was well arranged or not. With the introduction of carbon brushes, commutating poles, low-hysteresis iron, a better choice of high-grade insulating materials, high-speed prime-movers and machinery, and a better knowledge of electro-technique, the size of electric machines is so reduced that the cooling-surface is now so small that it cannot radiate the heat generated without the help of artificial ventilation.

Insulating materials are bad conductors of heat, and the windings from which the heat should be dissipated as quickly as possible are lagged with the very materials which render this process more difficult. The skill of the physicist and inventor should be applied to produce insulating materials capable of withstanding a higher temperature-rise. Pending advance in that direction, there are three methods by which the cooling can be improved, and consequently the size of electric machines reduced, namely: (1) to drop artificially the temperature of the medium in which the machine has to run, (2) to improve the orthodox way of air-ventilation, and (3) to develop new methods and use cooling fluids having a higher specific-heat coefficient.

The heat generated in open machines is carried off mainly by conduction from the heated molecules of air brought into contact with heat-conducting parts of the machine, and to a lesser degree by the eddying motion due to rotation of the armature and by metallic conduction.

It is important to bring a constant supply of fresh air into contact with the radiating surfaces, and this is ensured in many types of motors by mounting fans on the armature shaft so as to create a positive draught through the machine.

Mr. B. G. Lamme, Chief Engineer of the American Westinghouse Company, gives in one of his recent papers some very interesting figures respecting the velocity of the air in large machines. He mentions 5,000 to 6,000 feet per minute as being fairly common, and in some cases speeds of 10,000 feet per minute, which corresponds to 125 miles per hour. Such figures are abnormally high. In my opinion these high air-current velocities in many cases betray a weakness in the design of the machine. Air propelled at that speed has a tendency to move as a solid mass. The same layers are brought into contact with the surfaces to cool, the bulk of the volume of air which passes through the machine is ineffective by reason of the inherent bad heat-conductivity of the air, and the power absorbed by the fan is out of proportion to the ventilation obtained.

In the course of my experience I have found cases where the fan employed to cool the machine was so injudicially constructed as to create a vortex that kept the air contained in the machine practically in a closed circuit, with the result that the machine would have probably run cooler without a fan. Experiments which I carried out tend to show that the emissivity of a heated surface rapidly reaches a maximum with an air-draught of 3,000 feet per minute.

There is very little data available at present regarding the power which a fan should absorb per unit of heat dissipated under the conditions prevailing in electrical machines. Some authors mention 1 kilowatt for every 5 kilowatts, whilst others mention 1 for every 8 kilowatts. In some enclosed machines I have obtained as much as 12 kilowatts per kilowatt power of the fan. These figures, however, are misleading, because it is difficult to judge under what conditions they were obtained. The pressure necessary to send a sufficient quantity of air through the windings varies considerably with the design of the machine. In some cases a ½-inch head of water is sufficient to drive this air through; in others 3 inches are required.

New shapes of windings can be devised, and new ways ot building the essential mechanical parts, which would greatly enhance the efficiency of the cooling by decreasing the resistance to the passing of the ventilating air.

Unfortunately, the forcing of air through the machines is liable to give rise to breakdowns, due to the drawing in of dirt and oil with the incoming air, and to decrease of the ventilation by clogging of the air-passages.

These are the reasons why I became convinced long ago that some day the problem of building totally-enclosed motors that would compete in price with open machines would have to be faced.

If the problem of cooling open machines is in itself complicated, that of cooling a totally-enclosed machine is even more difficult. In the open-type machine most of the devices deal with a particular way of forcing cool air through the machine. In the case of totally-enclosed machines of the usual type, practically the whole of the heat generated inside must pass from the heated part to the contained air, from the air to the inside of the case, from the inside of the case to the outside, and thence to the outside air. In other words, the heat has to pass through a layer of bad heat-conducting material. By inserting a fan inside the machine, however, a circulation of the internal air is created, and this air will carry heat out by convection to the outside casing.

It appears from experiments that the air inside reaches a fairly uniform temperature, due to the churning effect of the fan. The total heat which can be radiated from such a motor is proportional to the surface of the motor, and it is obvious that this surface does not increase in the same ratio as the cubic contents of the motor, whereas the permissible output of an open-type machine is nearly proportional to the total volume.

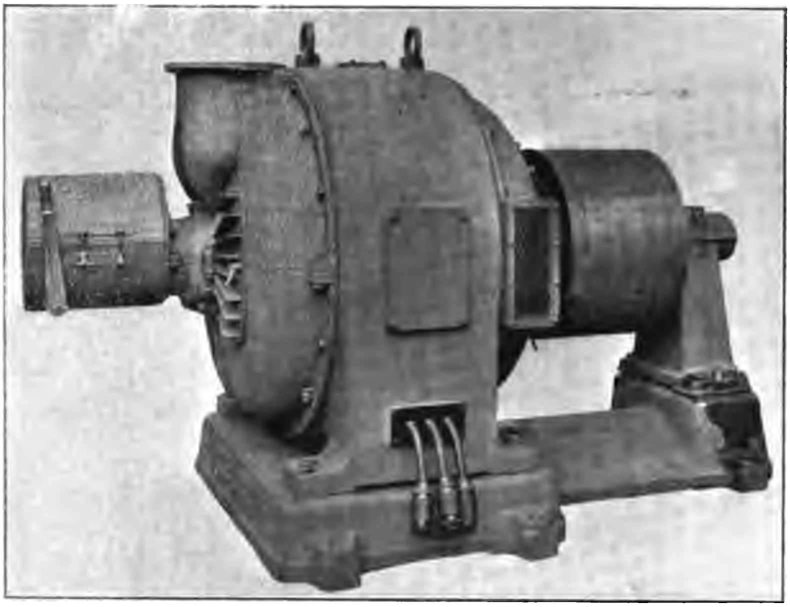

FIG 1.—350-HORSEPOWER THREE-PHASE PIPE-VENTILATED BRITISH THOMSON-HOUSTON MOTOR.

From this it will be seen that the ratio of the price of totally-enclosed motor to the price of open-type motor of the same power and speed is a quantity which grows rapidly with the size of the machine.

Attempts have been made to overcome these objections by building pipe-ventilated motors (Fig. 1); but such motors are not in reality enclosed motors and cannot be used in mines or chemical factories where there is a deleterious atmosphere.

Several methods of cooling totally-enclosed motors have been proposed, and might be classified under two headings, namely: (*a*) cooling-devices external to the motor; and (*b*) self-contained cooling-devices. In the first type the same volume of air is passed repeatedly through the machine, drawn in at one end

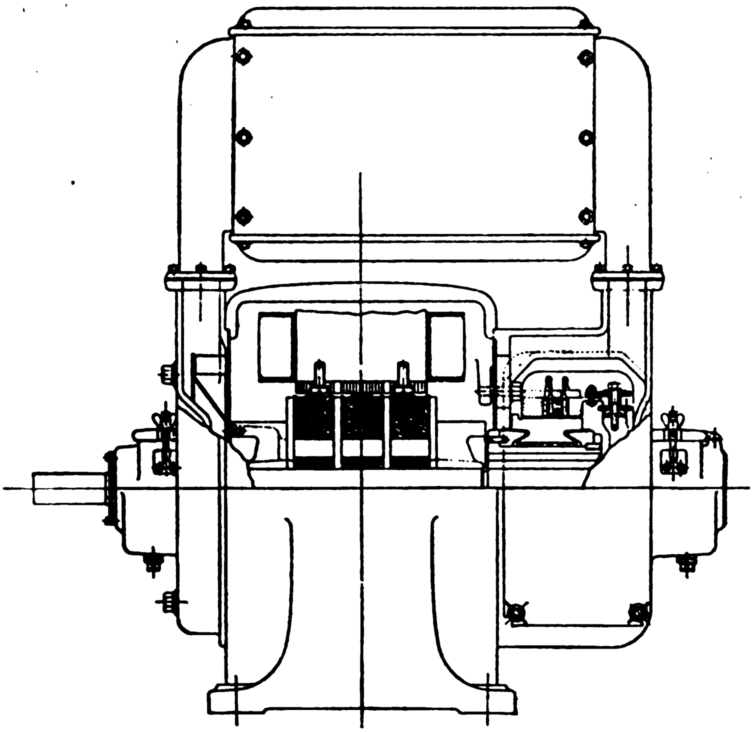

FIG. 2.—CROSS-SECTION THROUGH LO-THERMO DIRECT-CURRENT MOTOR.

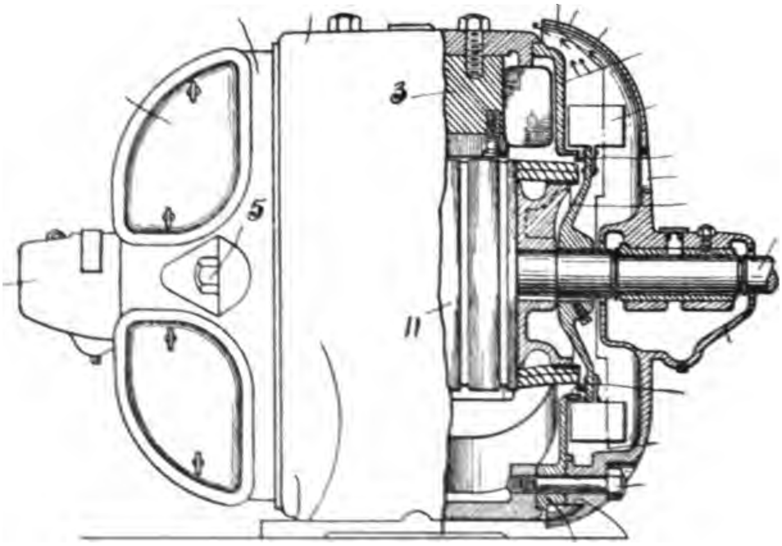

FIG. 3.—CROSS-SECTION THROUGH EARLY TYPE OF BRITISH THOMSON-HOUSTON TOTALLY-ENCLOSED VENTILATED MOTOR.

and expelled at the other, the circulation being completed between staggered ribs formed in the box-shaped foundation-plate.

In this manner the heat is transmitted to the surrounding foundations. The ribs may be hollow, and air or water may flow through them. This type of construction would appear to be efficient, but the extra cost and bulk due to the complicated foundation-plate is considerable.

A more successful means of carrying out the idea of an external radiator (Fig. 2) has been lately put on the market by Electromotors, Limited, of Openshaw, Manchester. In one from the radiator consists of a box with end pieces designed to fit on vertical trunk openings in the motor end covers, and through this box a number of thin metal tubes pass in a vertical direction. Inside the back end cover of the motor a fan is fitted on the armature shaft, and this causes a circulation of air through the machine and radiator-box. The heated air communicates the heat from the machine to the walls of the tubes, which are cooled by natural radiation.

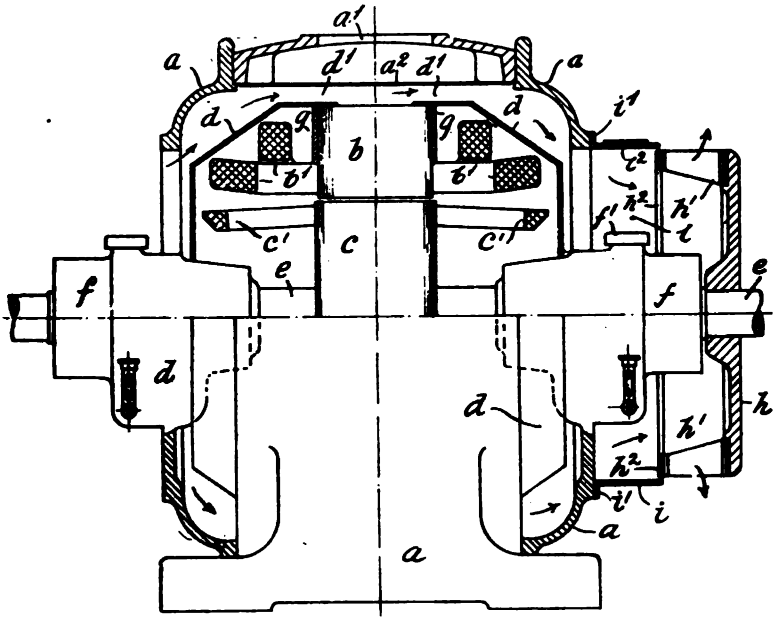

Fig. 4.—Cross-section through Totally-enclosed Three-phase Siemens Motor.

In another form of this invention the radiator-box sides are constructed of thin sinuous metal, with top and bottom covers, and baffle-plates inside the radiator, which cause the air to impinge in a thin stream against a large radiating surface. Part of the heat is radiated by the machine itself in the usual way of a totally-enclosed motor of the orthodox type. It is claimed that with this system it is possible to approach the capacity of the ventilated motor of the same frame size without the size of the radiator being excessive. The only objection to this system is the bulky superstructure.

An improvement which naturally suggests itself would be to extend the shaft of the motor and mount a fan with a suitable guard to deflect a stream of fresh air on to the radiator. This suggestion has been carried out in the direct-current motor of Electromotors, Limited.

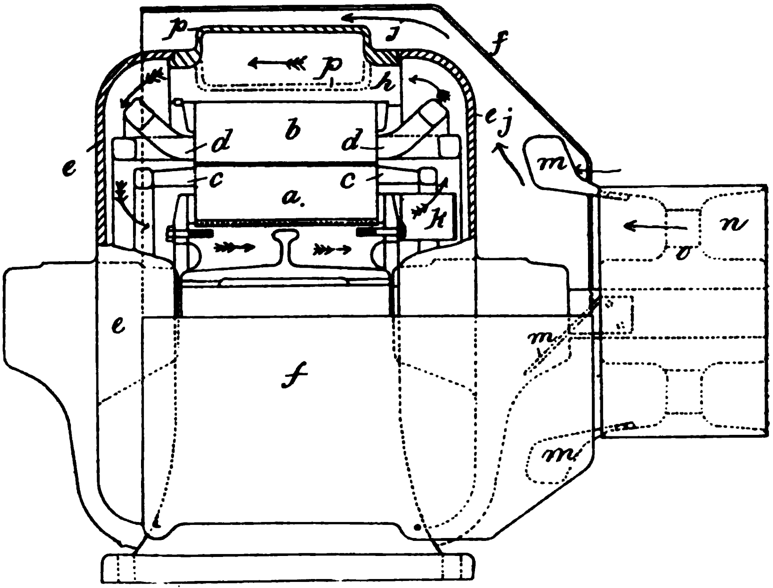

FIG. 5.—CROSS-SECTION THROUGH TOTALLY-ENCLOSED THREE-PHASE MAVOR-&-COULSON MOTOR.

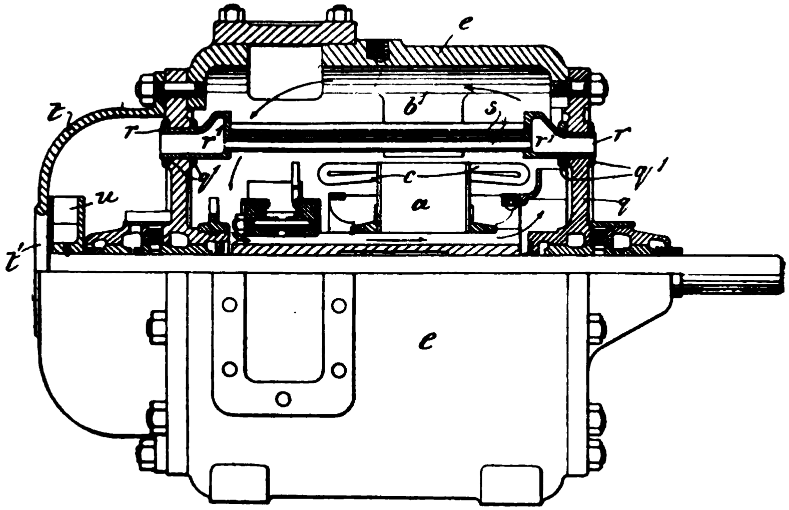

FIG. 6.—CROSS-SECTION THROUGH TOTALLY-ENCLOSED DIRECT-CURRENT MAVOR-&-COULSON MOTOR.

The foregoing methods of cooling entail the use of a radiator as a super- or sub-structure; the following are self-contained with the machine.

The earliest type of artificially-cooled totally-enclosed motor is illustrated in Fig. 3, which represents a cross-section of a direct-current machine. A fan is mounted at the end of the machine; this sucks air through holes in the outer cover, and forces it through a narrow gap around the motor-casing. This device was used by the British Thomson-Houston Company many years ago. It improves the cooling of the machine, but it is not really a " totally-enclosed " motor according to the definition of the term, because the fan-plate leaves a gap through which the outside air can penetrate partly into the interior.

The same may be said with regard to the system which has been proposed by Schröder and produced by the British Westinghouse Company.

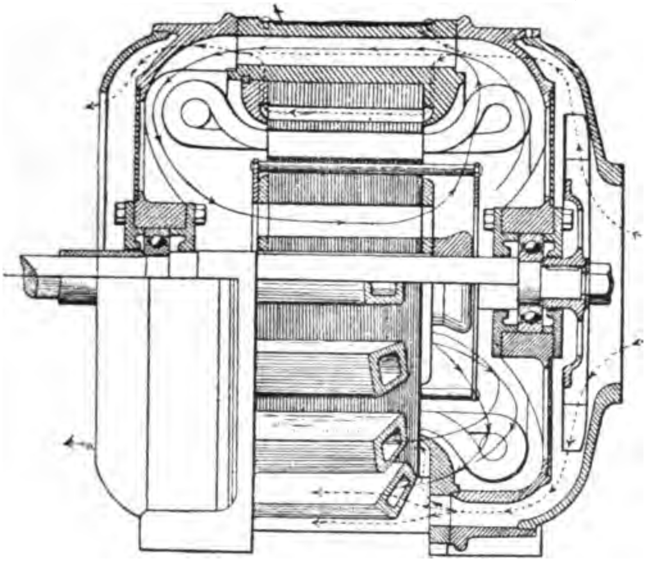

FIG. 7.—CROSS-SECTION THROUGH TOTALLY-ENCLOSED THREE-PHASE EMCOL MOTOR.

In Fig. 4 the machine is enclosed in a shell made of thin heat-conducting material inside the frame. The fan at the end of the armature shaft forces the air between the motor-casing and the inner shell. This method is an improvement on the previous one, as the internal heated air is closer to the external cooling air. Furthermore, a portion of the heat is carried by conduction to the inside part of the frame, which is also in contact with the cooling air. This method has been proposed by Messrs. Siemens Brothers, Limited.

A variation of this method is shown in Fig. 5, which is an arrangement proposed by Messrs. Mavor & Coulson, Limited. The casing is corrugated; a fan circulates the cold air inside the machine, whilst another fan circulates the cold air between this corrugated casing and a sheet-metal cover surrounding the machine. The superiority of this method over the other two is the increased cooling surface.

Fig. 6 shows an entirely new conception. The cold air is taken right through the machine by a series of pipes connecting the two end covers or flanges in the frame. The hot air, which is circulated in the machine by means of a fan, impinges on these pipes, to which it communicates the heat carried away from the armature.

In all these methods, however, the internal air plays the main rôle by conveying the heat to the cold circulating air, and this latter hardly comes into contact with the heated part of the machine, so that a very small portion of the heat is taken away by conduction. In fact, the hot air jackets the machine.

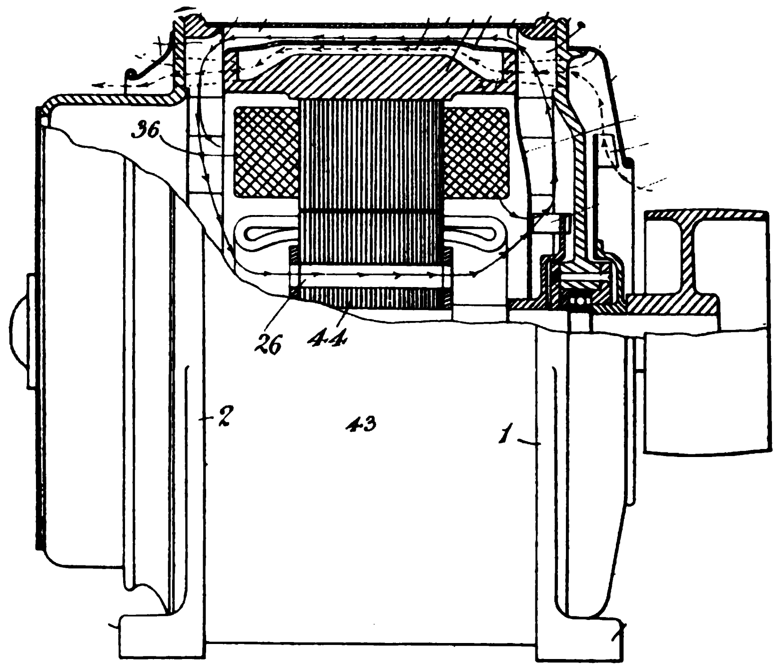

FIG. 8.—CROSS-SECTION THROUGH TOTALLY-ENCLOSED DIRECT-CURRENT EMCOL MOTOR.

I have endeavoured to improve upon these methods, and the results of my research in this matter are, I believe, a great advance in totally-enclosed machines. Fig. 7 shows a cross-section through an alternating-current three-phase motor. The chief characteristic of the invention is the circulation of the air through a cooling system cast integrally with the frame in such a manner that the external dimensions are not increased appreciably. The cooling-chambers are channels cast in the webs supporting the laminæ, so that the actual weight of a housing built according to this method is not greater than that of an ordinary standard motor. The cooling-channels are cooled by drawing cold air from outside through another series of channels so arranged that the cooling-air entirely surrounds the hot-air channels. The crux of the invention consists in crossing over the two currents of air so that the cooling-air is also in contact with the outside of the stator laminæ or magnet-ring. By this means a very large area of cooling-surface is obtained. The cooling-air does not enter the motor in any way, but merely blows through the space between the outside periphery of the laminæ and removable cover and around the tubes. The outer detachable cover allows the tubes to be cleaned and to prevent any fluff or dirt accumulating in the corrugation and may impair the efficiency of the fan.

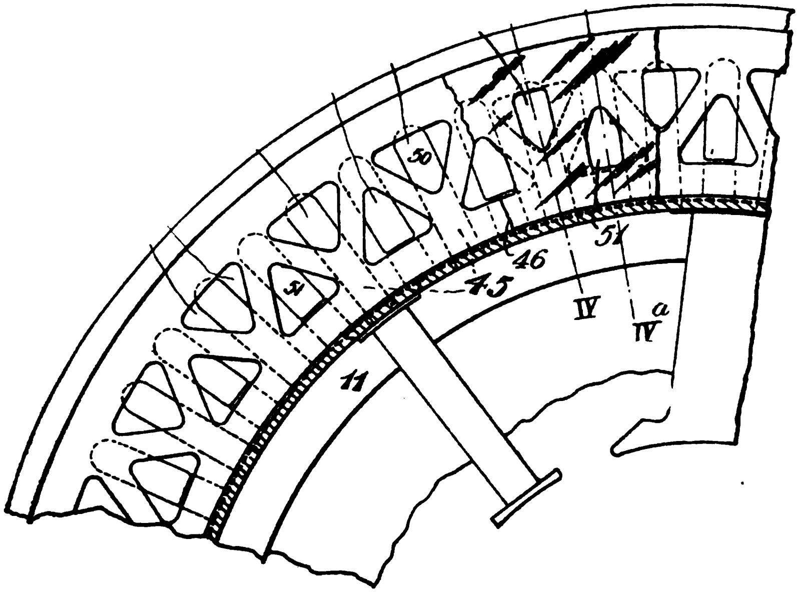

FIG. 9.—CROSS-SECTION THROUGH TOTALLY-ENCLOSED DIRECT-CURRENT EMCOL MOTOR

Mr. H. C. E. Jacoby has proposed to build direct-current motors on the same principle by surrounding the magnet-frame by two or more rings of sheet-metal. These rings are spaced apart to form annular chambers, which are connected respectively to the interior of the machine and to a supply of cold fluid, so as to permit of the hot air in the interior of the machine being sandwiched between layers or annuli of cold fluids, one of the cold fluid layers being in contact with the magnet-ring. Thus the frame of the machine is in contact with the cool air-supply, and the internal air is both cooled by the same air and by natural radiation through the thin sheet-metal cover in contact with the atmosphere (Fig. 8). The distribution of the cold and hot air to their respective chambers is effected by an end shield.

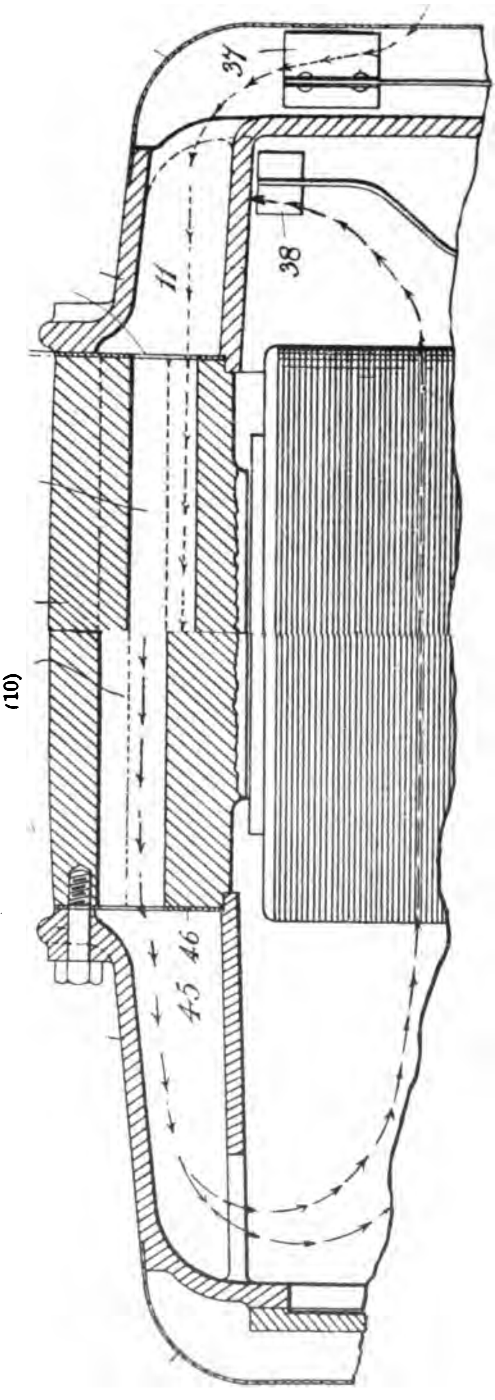

Fig. 10.—Cross-section through Totally-enclosed Direct-current Emcol Motor.

In conjunction with Mr. H. C. E. Jacoby, I latterly proposed to cast the magnetic-ring of direct-current machines with a multiplicity of longitudinal channels in such a way that the channels do not interfere with the proper distribution of the magnetic flux (Figs. 9 and 10). These channels are connected alternately with the interior of the machine and with the outside cooling medium. An internal fan circulates the hot air in one series of channels and a protected outside fan circulates the cooling-fluid in the other series of channels. Figs. 11 and 12 show a 10-horsepower three-phase motor manufactured by the New British Electric Supply Company, of London, the electrical portion of which was a standard design for a 10-horsepower four-pole open type 50-period machine, which on a six-hour full-load test showed a temperature-rise of only 54° Fahr. on the winding, the temperature-rise of the air inside the motor being 46° Fahr. When loaded to 14 horsepower, the final temperature-rise was 65° Fahr. on the winding, and of the air inside 59° Fahr.

For purposes of comparison, tests were taken on the same motor with the cooling system rendered inoperative, so as to bring the motor under the condition of an ordinary totally-enclosed motor. The results of these tests are shown by the curves in Fig. 13. It should be noted that the motor in every case was run at the current and voltage that gave the best efficiency for that particular load. As an orthodox totally-enclosed machine, it could barely be rated at 5 horsepower for continuous rating. At that load the losses are roughly half the losses at the 10-horsepower rating, which is shown on the diagram, and this enables me to formulate the following contention:—The output of an enclosed motor of this type with a given temperature-rise is the same as the output of a standard

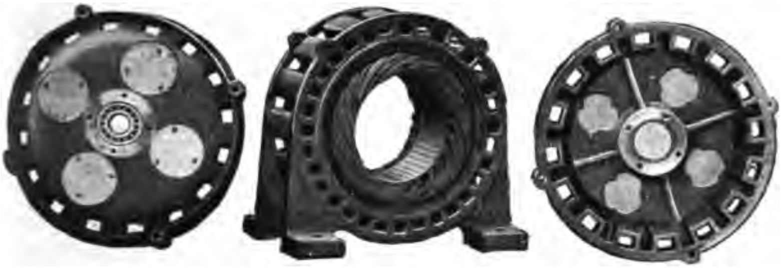

FIG. 11.—THREE-PHASE EMCOL MOTOR.

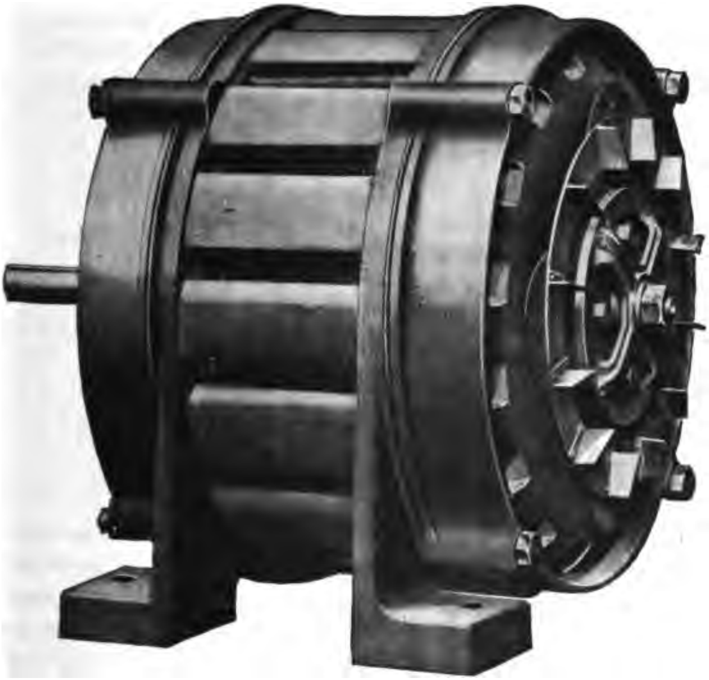

FIG. 12.—THREE-PHASE EMCOL MOTOR, WITH COVER REMOVED.

open-type motor of the same bulk and the same weight of active electric material. The output of an enclosed motor of this type is two-and-a-half times larger than the output of a standard totally-enclosed motor of the same dimensions and weight of active material for the same temperature-rise.

Since these tests were carried out, larger motors built under my patent have fully confirmed these contentions. Further improvements are being brought out in the design of these machines, and doubtless they will assist materially the application of electricity to such industries as coal-mining, steel and iron manufacture, chemical works, and last, but not least, traction. In this latter field the standard practice has consecrated the almost exclusive use of totally-enclosed motors, because in most cases the service conditions are such that the motors have a tendency to pick up the dust, dirt, and mud of the highways. The strenuous conditions of starting, stopping, and in many cases the high voltages, render the introduction of dust and dirt into the motor extremely dangerous to the reliability of the operation.

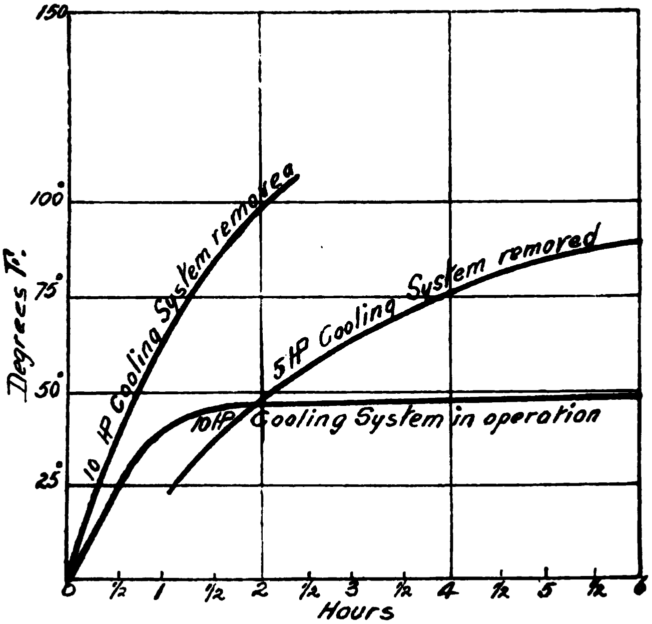

FIG. 13.—TEMPERATURE-RISE OF A 10-HORSEPOWER THREE-PHASE EMCOL MOTOR.

It is true that many very ingenious semi-enclosed motors have been devised to obtain ventilation and guard against the introduction of moisture and dirt; but in my opinion they are only half-way solutions. In coal-mining, especially in connexion with the driving of face tools, such as coal-cutters, it is necessary to have the highest possible power in the smallest compass if the working of small seams is to be rendered economical. I am convinced that, proceeding on the lines already indicated, much smaller motors than hitherto made can be produced of the totally-enclosed type, and I hope at a not very distant date to acquaint the members with further developments in that direction.*

Mr. H. A. McGuffie (Glasgow): The subject of the paper from an electrical point of view is of great interest—especially to those associated with the application of electricity to mining problems. Could the author state the approximate increase in cost of a motor of the description described—what is the percentage of increase, say, as compared with a standard totally-enclosed motor? Also what is the largest size of motor of this particular type that has been made? This is an important matter, particularly in these days of larger haulers, larger pumps, and sometimes very large totally-enclosed motors. Mr. Mossay might also state whether the introduction of radiators is going to have any effect on the space available on high-tension motors for arranging insulation? How likewise does he get over the trouble with the bearings and the oil-creepage. We generally find that matters are all right for a month of two, then trouble develops, and that is usually put down to the slight difference in pressure in and outside the motor.

Mr. A. H. Steele (Glasgow): Does the arrangement described by Mr. Mossay comply with the Coal Mines Act for fiery collieries? I think the time is coming when there will be no such thing in a pit as an open-type motor in-bye, and the sooner that time comes the better. If the motor described by Mr. Mossay is what he claims it to be, it will fill a great gap in this class of machinery for mines.

Mr. J. P. C. Kivlen (Uddingston): The principles involved in the design of the motor are entirely new. Indeed so much is that so that since the patents were taken out a number of other machines have been placed on the market, all of which, however, are more cumbersome in design and less theoretically sound in principle than the motor under consideration. I have thought for many years that the methods adopted for ventilating electrical machines have been arrived at without giving due consideration to the theoretical principles involved. The placing of a fan on a rotor or armature shaft seemed to be the only method employed, and no consideration was given to the passage of the air through that section of the machine it was necessary to cool. When it is remembered that the whole structure of electrical design is based on temperature-rise, it follows that any consideration given to the ventilation of a machine tends towards economy and increased efficiency. In my opinion British standard ratings are too liberal, and I have the feeling that Continental rated machines are quite safe to use under normal conditions and in normal temperatures. A national economic problem is involved here, as we shall have to compete with American and Continental manufacfacturers in the near future. Another important point appears to have been overlooked by designers, namely, the question of oil-creepage. Oil-creepage never seems to have been entirely eliminated. It is not so much the oil as the carbon deposit coming from the lamps that causes trouble in mines. Owing to the oil being a binding medium, it adheres to the windings. Owing to continuous breakdowns on heavy alternating-current rotors, I made some exhaustive tests of the compositions, and have found these to become white hot when heavy currents were passed through them. I found that the interstices of the windings became filled with this material, and on starting up the rotors broke down, due to short-circuiting. As a matter of fact, I found that the motors were equipped with fans that literally threw the oil and carbon on to the windings. Such a trouble could not occur with the motor designed by Mr. Mossay, because the fan circuit is entirely separated from the windings. It rather seems to me that this is the particular type of motor mining people have been looking for for some time past. The point, however, that is of more importance to us is whether the motor is applicable to mines operating under Regulation 132. A motor that is capable of being placed anywhere in a mine is, in my opinion, a most desirable asset to have on hand.

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* The thanks of the author are due to Messrs. Electromotors, Ltd., Openshaw, Manchester; Messrs. The British Thomson-Houston Co., Ltd., Rugby; and Messrs. The New British Electric Supply Co., Dalston, London, for kindly furnishing the illustrations of enclosed motors that were shown at the reading of the paper.

Mr. P. A. MOSSAY (London), in reply, said: Mr. McGuffie has raised the question of costs. That question, generally speaking, as the war has shown, is one of quantity. If you make the motors described in the paper in lots of one, twos, and threes, they will be more expensive than the open motors. I am fully convinced, however, that it is possible to manufacture these motors in large quantities as cheaply as the machines of the open type, but there is no question that with even a small production these motors will be considerably cheaper and smaller than the orthodox totally-enclosed motors. With regard to size, the largest motor built so far is a 50-horsepower direct-current machine, but this is by no means the limit. There is a point in the British regulations which in some way helps the totally-enclosed machines, as the permissible temperature rise of a machine of this type is 90° Fahr., whereas in the open machine the limit is 72° Fahr. The system is equally well applicable to high-voltage machines, because as a rule there is more room at the back of the punchings for locating the end connexions, and this automatically renders more space available for the cooling system. The question of bearings and oil-creeping is a purely mechanical point that is quite independent of the system of totally-enclosed motors employed, whether of the orthodox type or of the system described. If due care is taken in designing the bearings to avoid a considerable difference of pressure between the inner end and the outer end of the bearings, oil-creepage can be entirely avoided. So far as the point raised by Mr. Steel is concerned, I do not see any difficulty in designing the motor to comply with the restrictions in Rule 132 of the General Regulations of the Coal Mines Act. There are no great difficulties in making these motors entirely watertight. I am fully in agreement with Mr. Kivlen in all that he says with regard to the British standard ratings being too liberal. It was due to that fact that a great many German machines in the past came to this country, and that a very unfair competition was set up against British manufacturers.

The further discussion of the paper was adjourned.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM NOV. 3RD TO NOV. 30TH, 1918, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of Week.	Day of Month.	Magnetic character.	Intervals in hours (Greenwich mean time). 0h. to 2h.	2h. to 4h.	4h to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h.	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
	Nov		14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
Sun. ...	3	0	45′·0	46′·0	46′·5	45′·5	45′·0	49′·0	51′·5	50′·5	48′·0	47′·0	46′·5	46′·0	47′·0
Mon. ...	4	0	46·5	47·0	46·5	45·0	44·0	49·0	51·0	49·5	48·0	46·5	44·5	43·0	46·5
Tues. ...	5	0	46·0	46·5	46·0	45·0	44·0	49·0	51·5	50·0	48·0	47·0	46·0	45·5	47·0
Wed. ...	6	0	46·5	47·0	46·5	45·5	45·0	49·0	51·0	49·5	48·0	47·0	48·0	46·0	47·5
Thur. ...	7	0	47·0	47·0	47·0	45·5	45·5	50·0	51·5	50·0	48·5	47·5	48·5	46·0	47·5
Fri. ...	8	0	46·0	43·0	46·0	45·0	45·5	49·5	51·5	50·5	49·0	47·5	46·0	44·0	47·0
Sat. ...	9	0	45·0	46·5	46·5	45·5	45·5	48·5	50·5	49·5	48·5	47·0	46·0	43·0	46·5
Sun. ...	10	1	45·5	46·0	46·0	45·5	45·0	48·5	52·0	51·0	51·0	48·0	42·5	41·5	47·0
Mon. ...	11	2	43·0*	45·0*	49·0	47·5	47·5	48·5	51·0	50·5	47·0	37·5*	38·5*	38·0*	45·0
Tues. ...	12	2	44·0*	48·0*	52·0*	50·5	49·5	50·5	52·5	49·5	43·5*	38·0*	40·0*	45·5*	47·0
Wed. ...	13	1	43·0	48·0	48·5	49·0	49·5	49·0	49·5	47·5	40·5	40·5	44·0	44·5	46·5
Thur. ...	14	1	47·0	47·5	46·0	45·5	46·5	50·0	51·0	49·0	47·5	41·0	41·0	44·5	46·5
Fri. ...	15	2	46·0	47·0	50·5*	48·0*	45·0	49·0	50·0	48·5	40·0*	43·5*	45·0*	41·0*	46·0
Sat. ...	16	1	44·5	47·0	47·0	46·5	46·5	50·0	51·5	48·0	44·5	44·5	41·5	43·5	46·0
Sun. ..	17	1	47·0	47·0	46·5	46·5	46·5	49·5	50·0	49·5	47·5	45·0	45·5	45·0	47·0
Mon. ...	18	0	45·5	46·5	46·0	46·5	47·5	50·0	51·5	50·5	48·5	45·5	44·5	45·5	47·5
Tues. ...	19	1	46·5	47·0	46·0	45·0	45·5	49·0	51·5	51·0	49·0	43·5	41·0	43·5	46·5
Wed. ...	20	0	47·0	47·5	46·5	44·5	44·5	48·5	51·0	51·0	49·0	47·0	45·5	45·0	47·0
Thur. ...	21	0	47·0	47·5	47·5	45·0	45·5	49·5	52·0	50·5	47·5	45·5	44·5	45·0	47·0
Fri. ...	22	1	46·0	47·5	47·0	46·0	45·5	48·0	50·5	49·0	48·0	46·5	48·5	39·5	46·5
Sat. ...	23	1	40·5	40·0	43·5	46·0	49·5	53·0	55·5	54·0	53·0	46·5	48·5	44·5	47·5
Sun. ...	24	2	45·0	44·0	43·5	45·0	46·0	51·0	54·5	50·5	47·5	37·0*	43·5*	45·0	46·0
Mon. ...	25	0	46·0	46·0	44·5	44·5	45·0	47·5	48·5	48·0	47·0	46·5	45·0	45·5	46·0
Tues. ...	26	0	46·0	46·5	45·0	44·5	45·0	47·5	49·5	48·0	47·0	46·5	45·5	43·5	46·0
Wed. ...	27	0	44·0	45·5	44·5	44·5	45·0	47·5	49·0	48·0	46·5	45·5	46·0	45·0	46·0
Thur. ...	28	1	45·5	46·0	45·5	45·0	45·0	48·0	50·5	49·5	47·0	46·0	45·0	42·0	46·0
Fri. ...	29	2	45·5	46·0	46·0	45·5	45·5	48·5	49·5	48·0	49·0	54·5*	43·5*	37·0*	47·0
Sat. ...	30	2	39·5*	47·5*	45·5	45·5	46·0	49·0	49·5	50·0	50·5	47·5*	41·5*	43·5	46·0

Diurnal Inequality (*i.e., departure from mean value for day*).

	1h.	2h.	3h.	4h.	5h.	6h	7h.	8h.	9h.	10h.	11h.	12h.
November, 1917 ...	−0′·9	−1′·0	−0′·6	−0′·3	−0′·7	−1′·2	−1′·9	−2′·8	−2′·9	−1′·5	+1′·4	+3′·1
October, 1918 ...	−1·4	−1·5	−1·3	−0·9	−0·7	−1·1	−2·1	−3·1	−3·2	−1·3	+3·0	+5·0
October, 1917 ...	−1·5	−1·4	−1·1	−0·8	−0·8	−1·8	−3·5	−5·1	−4·7	−2·2	+1·5	+4·4

	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
November, 1917 ..	+3′·3	+3′·2	+2′·8	+2′·0	+0′·8	+0′·3	0′·0	−0′·1	−0′·7	−0′·9	−0′·8	−0′·9
October, 1918 ...	+6·0	+5·8	+4·6	+2·6	+1·1	+0·4	−0·6	−1·6	−2·3	−2·3	−2·4	−1·9
October, 1917 .	+5·5	+5·5	+4·5	+2·9	+2·1	+1·3	+0·5	−0·1	−0·7	−1·2	−1·5	−1·8

* Large disturbances during this interval.

Mean Value for Month.

November, 1917.	October, 1918.	October, 1917.
14° 56′·6.	14° 47′·7.	14° 57′·5.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G.M.T.

Character "0" means a day wholly free from any but small disturbances.

,, "1" ,, ,, part or all of which is moderately or considerably disturbed.

,, "2" ,, ,, part or all of which is highly disturbed.

The normal value for an hour is the mean declination for that hour in the month, derived from quiet days only, or from all days excluding those of character "2." On a day of character "0" declination at any hour will usually be within about 3′ of the normal. On a day of character "1" the departure from the normal will usually not exceed 5′, but it may occasionally be as much as 10′, or even more. On a day of character "2" the departure from the normal will seldom exceed 20′, but departures of 30′, or even on extreme occasions of 1° or more, may occur.

The above values were obtained from measurements made after "smoothing" the curves.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
DECEMBER 14TH, 1918.

MR. C. C. LEACH, COUNCILLOR, IN THE CHAIR.

DISCUSSION OF PROF. F. W. HARDWICK'S PAPER ON "THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION."*

Prof. **HENRY LOUIS**: Prof. Hardwick's paper refers apparently only to the training of students who are preparing to become general managers, viewers, agents, or consulting engineers—that is to say, to occupy what are usually looked upon as the higher branches of the mining profession. The training of officials up to the rank of under-manager is equally necessary, but this requires institutions, methods, and teachers of an entirely different type, and must therefore be considered quite apart from the other form of training. It will, of course, be always possible for a student of exceptional ability to pass from the one category to the other, just as it is possible for a man to commence at the coal-face and finish at the head of the mining profession. In drafting general schemes, however, whilst these must be sufficiently elastic to allow the exceptional men to make the fullest use of their abilities, the schemes themselves must be devised to suit the average man and not the brilliant exception. Since Prof. Hardwick has not dealt with the training of colliery officials, nothing further need be said on this head, except to point out its necessity.

The main point in the paper appears to be the advocacy of a central bureau where information can be obtained concerning the education and training required for the mining profession. From my own experience I doubt whether such a bureau is really required: there are mining colleges in every district in England, and no one is so remote from one or other of these that he cannot get into direct touch with it, or obtain full information by post. If any central agency is needed, it would probably be best to have one in conjunction with a Mines Department for the United Kingdom, on the lines suggested by Sir Lionel Phillips in his recent report.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 94.

Whilst there is much in Prof. Hardwick's paper with which I cordially agree, there are a few points on which I differ, to which I shall refer.

With regard to school-training, I hold very different views from his; in my opinion, the proper object of a school training is not to lay the foundation for the study of special technical subjects, but to give a boy a thorough liberal education on the broadest possible basis. That is the time when a boy should learn his own language thoroughly, as well as acquire a knowledge of one or two others: I still hold that for this purpose a boy should be taught a fair amount of Latin. Educational subjects such as geography and history should be taught thoroughly, and the boy should also be given a thorough grounding in the more elementary parts of mathematics and allied subjects; he should be taught drawing and also general science, not necessarily any one science in particular, but scientific methods and principles in general. If he does not receive a thorough liberal education at school, he will never get it afterwards, so that the above is my ideal of what the school education of the future engineer ought to be.

With respect to practical work, my practice for some time past has been to recommend lads, as soon as they have passed their matriculation or school-leaving examination, to put in from three to nine months as working apprentices in an engineering works, in order to familiarize themselves with the workmen's point of view, and at the same time to gain an insight into ordinary mechanical engineering, an acquaintance with which is necessary whatever branch of engineering a man may subsequently take up. I do not believe in a lad being kept so long at practical work as to get him out of the habit of book-learning, which would interfere with his College career; the method I have indicated here is one that I have tried repeatedly, and found highly successful.

In reply to Prof. Hardwick's question as to intermittent periods of practical work at the colliery—for example, work done during the long vacation—this does count towards the minimum period demanded by the Coal Mines Act.

With regard to articled pupils, I think that this system of entry into the mining profession should be discouraged. It used to answer admirably in the old days, when the demands made on a mining engineer were far less complex and when scientific methods were practically unknown. There seems to be a great consensus of opinion at present in favour of the view that a University education is essential for a properly qualified mining engineer. The system of pupilage is becoming less and less common, and in view of the great increase in highly specialized scientific knowledge that is now required, it will doubtless tend to disappear entirely.

It may be further noted that Prof. Hardwick has contributed nothing to the solution of what I have always found to be the greatest difficulty in respect of lads whose families are not in touch with the mining profession, namely, how to get taken on at a colliery after their College course is finished. This difficulty is, of course, greatest where the lads' parents are unable to pay a substantial premium. This has always struck me as the weakest link in the chain of mining education: its solution lies in the hands, not of the teaching institutions, but of the collieries themselves; and in my opinion one of the great needs of the day is the provision of a considerable number of scholarships of a similar type to that recently founded by the Ebbw Vale Company at Armstrong College—scholarships given by large collieries or large colliery-owners, which give a lad, who has taken a good degree at College, enough to live on and three years' employment in a pit, so as to enable him, at the end of that time, to sit his colliery manager's examination, thus completing the connecting link between College and colliery.

Mr. Mark Halliday (Durham): The Engineering Training Organization referred to in the paper deserves close attention, and anything that can be done to improve the educational facilities of the mining profession ought to receive most careful consideration. I think we are all agreed that, generally speaking, there is much to be desired in present-day mining methods, and that education, in some degree, is essential to accomplish this object. The question of the educational standard is one upon which there has been, and is, great variety of opinion. Now that the subject of education is being so much discussed, it is fitting that some reference should be made to the degree of learning desirable to equip a man for a responsible post in mining engineering. A certain standard is already set by the requirements of the Coal Mines Act for Certificates of Competency, but it can hardly be said that it is sufficient. At all events, that part of the paper dealing with mechanical engineering subjects can only be classed as elementary. It is upon this section of mining education that, as a mechanical engineer, I wish to base my remarks. Mining operations are becoming more and more dependent upon the application of machinery for economical working, and require a more specialized knowledge of mechanical principles than is at present demanded of a colliery manager in the Home Office examinations. It is too much to expect it from him, because there is so much work entailed in connexion with mining proper that the average man cannot in his apprenticeship become possessed of expert knowledge in all the subjects related to it. Even in a University course for a degree or diploma in mining—which is the highest professional standard of education prevailing in that branch—the variety of subjects is such that it will not admit of an advanced knowledge in many essential studies, because there is only time to learn general and elementary principles. In order to meet this defect, I would suggest several departments for specialized study, to enable a man, after a general education, to concentrate on one of them, and thus have a fair chance of becoming expert in one particular branch of the profession.

As far as I know, there is not any course of the University standard which provides a special training for engineers in mining machinery. In most Universities and Colleges—certainly in Armstrong College—the mechanical engineering part of the course for a degree or diploma deals with general engineering principles and specializes in marine engineering. It is very rarely that reference is made to mining machinery except in so far as elementary parts are common to all classes of machinery. Some people will defend the existing system on the assumption that if a man applies himself seriously to the courses provided, his general knowledge of engineering principles will then enable him to adapt himself readily to conditions prevailing at coal-mines. That is true, but in these days of specialization we require, for a better educational system, something more than general principles. Specialized education has been applied to marine and naval engineering for some considerable time, with the result that this country maintains its supreme position in that branch of industry. There is quite as much scope for one to concentrate one's studies on mining machinery as there is in that for propelling ships; and it appears to me that properly organized courses, with suitable laboratory apparatus, is bound to yield good results in a comparatively short time.

If schemes for the improvement of mining education do materialize, this branch of the subject should not be lost sight of, and it should form an essential part of all mining departments of Universities and Colleges.

With regard to research-work in the various branches of mining engineering, it would be a distinct advantage to have research laboratories attached to the Colleges, to enable men, with certain prescribed qualifications, to have access to such places. Means would thus be provided for obtaining experimental data upon problems encountered in actual practice; in fact, the practical man possessed of a College training ought to have a type of mind that is continually in search for new things, and research laboratories will give considerable assistance and encouragement in that direction.

If specialized courses should actually meet with favour, and if they should be extended to all branches of work related to coal-mining, such as electrical engineering, chemistry, coke-oven practice, bye-products, etc., then I venture the opinion that the mining industry will benefit enormously.

Mr. H. F. BULMAN (Acklington): Prof. Hardwick's proposal that The Institution of Mining Engineers should issue an authorative statement with regard to the best training for mining students has much to recommend it. Such a statement, if well drawn up, would be likely to increase the number of suitable men entering the profession, and also to improve their training. As outlined by Prof. Hardwick, it should give clear and definite indication of what is required, some guidance as to the courses available, and the facilities for obtaining the needed education. A comparative table of the courses at the various Colleges which are " approved " would also certainly be useful.

The problem seems to be: how can the student acquire the largest possible amount of practical experience and useful scientific knowledge bearing on his work in the shortest possible time? It should be recognized that the work and the qualities of a resident colliery manager are not the same as those of a consulting mining engineer. Well-trained men in both capacities are essential to the wellbeing of the industry, but the training need not be the same. Broadly speaking, in the case of the colliery manager the practical training should predominate, and the scientific training in the other.

With regard to the vexed question of how the practical and the scientific trainings may be best co-ordinated, it is of the first importance that a student should be keenly interested in his work. The average British boy is not naturally fond of intellectual exertion, and as a mining student he is more likely to pursue his scientific studies to advantage if he realizes how they will help him in his future work. If he knows enough of practical mining to make him appreciate the value of scientific training, he will derive more benefit from it. This consideration points to the " sandwich " system as defined by Prof. Hardwick, or some modification of it, as being the best. As one of the great industries of the country, coal-mining for its personnel should be able to draw on the best the country can supply.

What capable and energetic men want is useful, interesting, and remunerative occupation. As the late Mr. Emerson Bainbridge once wrote: " The profession of a mining engineer offers to those who have to choose a certain business occupation, what may be considered a special advantage in the fact that there is no professional career which requires a certain amount of knowledge of such an interesting variety of scientific subjects."

Objections to the profession which one sometimes hears are that there is not much prospect for a man unless he has influential friends or relatives to back him, that most of the appointments are given to practical pitmen, and that scientific knowledge is not valued and finds no reward. If scientific training is wanted, it must be taken into consideration when appointments are made.

" A wider appreciation of the value in industry of University rank " will be secured by a closer alliance between industry and the University. There should be more co-operation between practical mining men and University professors and scientists. Those who control appointments should unite with educationalists in picking out and encouraging likely men, and the picking-out should include not only College students, but also promising youths at the collieries, so that they may get the education they need.

The Coal Conservation Committee has made a suggestion which deserves attention, namely, that scholarships should be provided to enable promising students who have distinguished themselves in the examinations for Certificates of Competency to undertake research-work.

Prof. WILLIAM GARNETT (London County Council Education Office): When I was in Newcastle I was very anxious to secure some arrangement by which pupils could attend College classes during part-time, devoting the rest of their time to work at the mines, believing that such division of time was best in the interests of the majority of mining students; but I found that the interpretation placed on the Coal Mines Regulation Acts would not permit such divided time to be counted. A shoeing-smith or a man employed entirely on a wagonway aboveground, " in or about a mine," could count the time, but not so a student who spent three days a week in the mine and the other three days under a professor in College. I found that the Government of the day were prepared to introduce a short Bill to meet my wishes if I could give an assurance that it would be unopposed, but unfortunately the miners' representatives, although entirely in favour of my proposal, were pledged to raise other questions if any measure dealing with coal-mines were introduced into the House of Commons, and these questions were bound to be opposed. The difficulty was surmounted later on, but not until I had left Newcastle.

In connexion with coal-mining, as with other branches of engineering, there will always be a difference of opinion on the question whether a boy on leaving school should go at once to the Technical College for a continuance course of study extending over, say, three years, or should proceed at once to the mine or engineering works for a year or more before starting on his College course, or should combine practical and theoretical instruction in some form of sandwich system, which may be regarded as a compromise between the two. This difference of opinion continues to exist, because there is a difference in the mentality of different pupils. Some boys have sufficient power of imagination to realize engineering problems which are described in College lectures or in text-books with the vividness necessary to enable them to appreciate their practical importance and the sufficiency of the solutions which are presented to them. Boys of this type of mind can advantageously proceed directly from school to the Technical College, and they will recognize the relations between laboratory work on a small scale and industrial work on a large scale, as well as the bearing of pure science upon industry. They thus gain the advantage of continuity in their educational work, and deal with the mathematical and scientific problems presented to them in their College course before they have forgotten their school work, or lost the habit of learning from books or oral teaching.

On the other hand, there are many boys to whom books and oral teaching are mere words, unless they have had practical experience of the subjects treated. To them a lecture on the indicator-diagram, or on some of the aspects of the problem of haulage or winding, would appear to have no more direct bearing on their lives than the memory of the thirty-six exceptions to the rule that Latin nouns ending in " is " are feminine. Such boys are not incapable of becoming engineers, but to them experience of the mine or the works before proceeding to their College course is indispensable. It necessitates some revision of school work when the pupil enters College, and perhaps a little time is wasted in recovering studious habits, but this is inevitable with pupils of this type of mind. The break between school and College should not generally exceed a year, unless provision is made for the continuation of theoretical studies under supervision during the evenings, because the habit of learning from books is easily lost at this stage of life.

Even in the case of the boy who can advantageously proceed direct from school to the Technical College, it is most important that some experience of the mine or workshop should be acquired before the end of the College course, and in this connexion the sandwich system has proved to be of great value in mechanical and electrical engineering. When in Newcastle I found that our most efficient students were those who had spent some time in the mine or workshops, dividing their time between that and the College course.

I suppose that all parties are agreed that a boy who is to become a mining engineer should remain at school until he has reached the standard of efficiency of the first school examination of the Board of Education at the age of 16 or 17, and that his school course should include both mathematics and physical science, together with English language and literature, and a modern language, as recommended by Sir J. J. Thomson's Committee. Some boys may advantageously remain at school for another two years, until they have reached the standard of the second school examination, and during that time should study mathematics, mechanics, physics, chemistry, and geology, in addition to a modern language or two and English literature; but presumably the majority of mining students for some time to come will leave school at the stage of the first school examination.

DISCUSSION OF MR. CHARLES J. FAIRBROTHER'S PAPER ON "RECORD OF GAS-PRESSURE FROM A BOREHOLE."*

Mr. **CHARLES J. FAIRBROTHER** (Dannhauser, Natal) wrote: In reply to Mr. Coulson's statement that the pressure was much less than had been recorded in coal-seams in the County of Durham, I would point out that this was not anything like the final pressure, but only that at which it began to lift the casing. The final pressure must have been very much higher in order to blow out the water from the hole against a head of some 770 feet.

Mr. Atkinson has questioned the gas having come from the coal-seams, and suggested that it might come from the strata above or below. It certainly did not appear at any time before the coal was struck, and the maximum pressure was not reached until the hole was well into the bottom seam. The boring was continued for several feet into the floor of the lower seam, but there was no indication of any higher pressure there.

The conditions in Natal can hardly be compared with those in England, as the seams are all intersected by whin dykes. The plans of a Natal colliery show a perfect network of these dykes running in all directions. As these dykes do not allow of the passage of the gas, each area becomes a small coalfield, very often charged with gas and water. The size of these areas vary greatly, but in the district described they are on an average about 700 feet from dyke to dyke. It becomes quite a problem to open out a new area, say, 3,000 to 7,000 feet from the shaft-bottom, with all the old workings lying behind.

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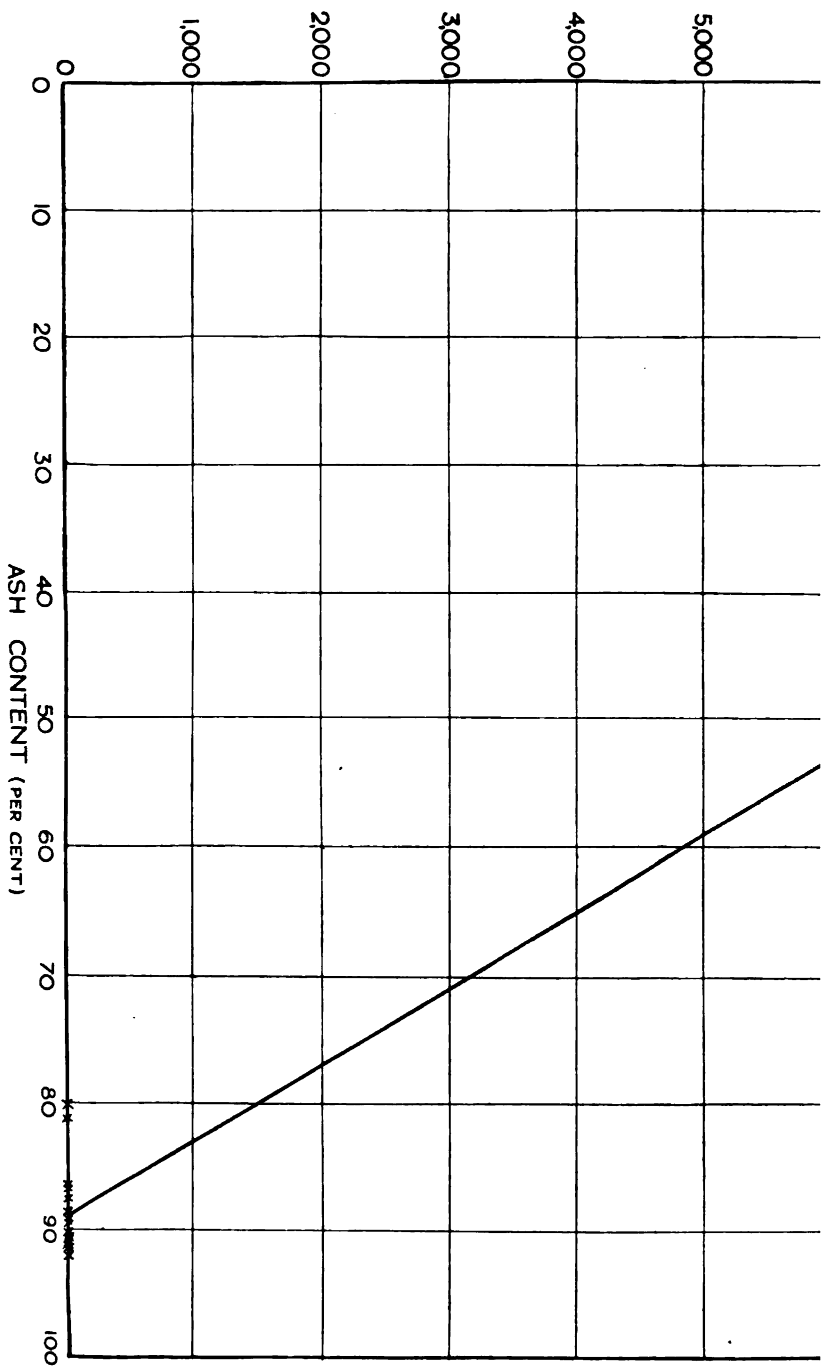
* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 6.

The Institution of Mining Engineers,
Transactions, 1918-1919.

To illustrate Mr. Thomas James Drakeley's Paper on " The Relat

FIG. 1.—PLOTTED



The Manchester Geological and Mining Society,
Transactions 1918-1919.

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THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING.

HELD AT THE UNIVERSITY OF LEEDS, OCTOBER 17TH, 1918.

MR. W. D. LLOYD, PRESIDENT, IN THE CHAIR.

PEAKE MEDAL.

The PRESIDENT (Mr. W. D. Lloyd), on behalf of the Council, awarded the Peake Medal to Sir William E. Garforth, LL.D., in appreciation of the very great services he had rendered to the Midland Institute and to the mining industry.

HIGH TEMPERATURES IN DEEP MINES.

Sir WILLIAM GARFORTH expressed his sincere thanks for the honour which had been bestowed on him, and proceeded to speak on the question of high temperatures in deep mines, which was raised by Mr. Blake Walker in his valuable Presidential Address to The Institution of Mining Engineers.*

Mr. Walker has reminded us that during the last half-century we have been working the shallower seas of coal, where the conditions of temperature are not such as to be prejudicial to human labour, and that we are now confronted with the problem of getting coal from depths where the natural conditions will make the result of human labour less effective.

In a paper on "Abnormal Temperatures," Dr. Haldane, the eminent physiologist, states that—

> "In warm air, or a warm climate . . . . the wet-bulb temperature . . . . measures the physiological inconvenience caused by the heat. . . . . Moving air cools or warms the body more than still air . . . . in a good current of air, a wet-bulb temperature several degrees higher than 88° could be borne. . . . . When the body temperature begins to rise owing to wet-bulb temperature, it does not stop rising . . . . till death occurs, or till removal to cooler surroundings."†

In connexion with Dr. Haldane's investigations, and the cases cited of the ill-effects of working in an atmosphere of high temperature, which are being experienced at the present time in the Doncaster area, Mr. Blake Walker asked: "Can these conditions of working with a wet-bulb of 88° Fahr. be mitigated on a practical scale so as to make physical exertion healthy and efficient?"

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 211.

† *Trans. South-Eastern Union of Scientific Societies*, 1917, pages 72-73.

With respect to this question, might I remind you that nearly fifty years ago the Royal Commission appointed to enquire into the probable duration of the English coalfields stated that the great natural difficulties connected with working seams of coal at depths exceeding 3,000 feet were due to the increased temperature and the difficulties of maintaining the area of the roadways, owing to the effect of the superincumbent weight. With regard to the former, the Committee concluded their report, which was dated July, 1871, as follows:—

> "The depth at which the temperature of the earth would amount to blood-heat, or ninety-eight degrees is about three thousand feet. . . . . Beyond this point the considerations affecting increase of depth and temperature become so speculative that the Committee felt it necessary to leave the question in uncertainty: but, looking to possible expedients which the future may elicit for reducing the temperature, they considered it might fairly be assumed that a depth of at least four thousand feet might be reached."*

The Report of the Royal Commission on "Coal Supplies," dated January, 1905, states that—

> "So far as we know, there are no actual coal-workings at depths exceeding 4,000 feet, and the conditions which will be met with at such depths are still largely a matter of conjecture. . . . . Hitherto no special appliances have been tried or required in order to cool the workings in deep mines, the necessary reduction of temperature having been obtained by brisk currents of dry air. The evidence shows that the temperature could not be reduced more than ten degrees without special means. It is not easy to determine the maximum temperature which is consistent with the healthful exercise of human labour. . . . The evidence shows that it is essential that the air should be kept dry."†

Having regard to Dr. Haldane's report, it must be admitted that the time has arrived when means should be taken to deal with the difficulties which those investigations so clearly pointed out, as to the detrimental effects of continuous working under certain conditions of high temperature.

Some of those present may be aware that two years ago the Advisory Council for Scientific and Industrial Research appointed a committee of representatives from the various mining districts of the country. A sub-committee was also appointed, to consider the "control of atmospheric conditions in hot and deep mines." The report of this Committee for the present year stated that, owing to the difficulty of obtaining the services of suitable assistants, and the members of the Committee having been constantly engaged in war work, it had only been possible to make limited progress, which, however, was likely to lay the foundation for future work.

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* *Report of the Commissioners appointed to Inquire into the Several Matters relating to Coal in the United Kingdom*, 1871 [C.435], vol. i., page viii.

† *Final Report of the Royal Commission on Coal Supplies*, part i., General Report, 1905 [Cd. 2353], pages 3-4.

With a view to again bringing this important matter to notice, and to devising means from which improvements might be obtained, I wish to place before you certain suggestions which have presented themselves to me during my connexion with the deep workings in certain collieries in Yorkshire, Lancashire, and Cheshire. The deepest shaft in Great Britain is at the Ashton Moss Colliery, of which I cut the first sod in 1875, and subsequently I was associated with the colliery as managing director for upwards of twenty years, or until four years ago, when I ceased my connexion with it. At this colliery the Saltpetre and Black Mines are worked to a depth of 3,340 feet, with a natural temperature of 91 degrees. From my experience at these and other collieries, I feel justified in stating that during the last thirty years many improvements have been made which will be as essential in working seams of coal at 4,000 feet as they have been within recent years in mines at a third of that depth.

Amongst other improvements, a safety-lamp can be claimed (principally due to the valuable experiments of Mr. Charles E. Rhodes) which is capable of withstanding an explosive current travelling at a high velocity.

The introduction of the electric light (both in the case of the hand-lamp and the fixed light) has also proved most useful at the coal-face in traffic arrangements, and in sinking and tunnelling operations.

The modern fan has been so perfected that it is capable of inducing a greater volume of air to circulate against a high resistance, and with fewer liabilities to breakdown.

Various kinds of high explosives have been substituted for gunpowder, and many years' experience of the best of these has proved that they were comparatively safe at the coal-face under the Government restrictions affecting their use. They are certainly safe when used in stone-work where there is no danger from firedamp or explosive dust. With such explosives, large roadways at a depth of 4,000 feet can be made at a cost which in comparison with that incurred in shallower seams would certainly not be prohibitive to the working of deep seams.

The longwall method of working coal has been further improved by mechanically cutting the seam in straight lines. The depth of the undercut—5, 6, or 7 feet—of the modern coal-cutter is also more advantageous, as it facilitates the easier fall of the coal, which the old cutters, with a 3-foot undercut, did not accomplish. The use of these machines, with their deep and straight cut, permit of the coal-face being pushed forward at a greater rate than when working with the pick and shovel, and the coal-face is subjected for a shorter time to the crushing effect of the overlying strata. The straight line of cut also produces the straight line of break in the roof, allows straight and systematic timbering to be carried out, minimizes the loss of life and injuries to workmen, and causes the least disturbance to the overlying seams of coal, with less damage to surface property. The straight line of coal-face has also opened the way to underground conveyors, which will prove another help in reducing the arduous labour of the miner, will reduce the number of roads required, and at the same time will assist in increasing the output of coal.

Successful systems of haulage have been in operation for many years past in seams from 1,500 to 2,000 feet deep, and these will be equally applicable to the deepest mines, when supplemented by secondary haulage, and will displace ponies, which are less able to withstand the effects of high temperature than human beings. At a certain colliery in South Wales, 2,000 tons of coal per day are dealt with by mechanical haulage, and the use of ponies has been dispensed with.

The special experience already acquired in sinking shafts through difficult ground to depths of 2,700 feet, and in constructing openings from the shaft to the mine, will be very helpful in the future.

Steel and other materials of a greater tensile strength, with less weight and bulk, will, on the lines of continued improvements, be provided to meet future requirements.

There will be a greater percentage of small coal, due to increased depth and to the crushing effect of the overlying weight, but modern experience has shown that small coal, which formerly realized such a very low price, has in recent years become a valuable asset owing to the introduction of plant for the recovery of the bye-products.

In recent years explosions attended with loss of life have been less frequent than formerly, and it is to be expected that freedom from serious accidents will continue.

The foregoing brief summary suggests that the modern improvements which have been found useful in coal-seams at a depth of 2,000 feet may be equally advantageous at depths of 3,000 to 4,000 feet, provided that the atmosphere of the mine can be rendered as suitable for human effort as in seams of less depth.

In order to effect a reduction in the temperature of the mine, some modifications will be required from the systems which have hitherto been adopted of conveying the intake air along certain roadways in the mine to the coal-face and returning the vitiated air along other roads in the same mine, or plane, to the upcast shaft, which systems have been and are suitable in mines with a temperature of 75° Fahr. or less in the return airways or natural strata.

With a view to devising methods to do this, I may point out that, whilst colliery officials have been engaged in increasing the safety of mines and supplying a larger output of coal to meet the ever-increasing demand, members associated with practical and scientific societies have been equally engaged in bringing forward new inventions. The result has been that we have now greatly improved engineering appliances of various kinds worked by electricity and compressed air. Even a brief description of these improvements would exceed the limits of these notes, but, shortly, I may state that colliery-owners and their officials readily admit that, without the assistance of men of science, inventive mechanical and electrical engineers, and members of the Iron and Steel Institute, British collieries could not have produced an annual output of 287 million tons of coal, which was the output of the United Kingdom in 1913.

In my opinion information is now required from the makers of modern refrigerating plants, of their experience in cooling atmospheres, so that colliery officials may consider how similar systems may be utilized for reducing the temperature in deep workings from an unsuitably heated atmosphere to one comparable with the atmosphere of shallower mines. Refrigerating plants have been working successfully for many years, and large quantities of air are being cooled and dried in connexion with blast-furnace plants.

In 1906 I obtained a specification and tender to reduce the temperature of a certain volume of air from 90° to 75° Fahr., and, some time before the outbreak of war, an expert accompanied me in an underground inspection with a view to supplying a plant capable of cooling the temperature of certain working-places from 75° to 60° Fahr. The estimates I got at the time were, I considered, very reasonable as regards the cost of installation.

Modern improvements have led to the extended use in mines of compressed air in lieu of steam, and have, I believe, brought nearer to those engaged in coal-mining the necessity for an early introduction of intense cooling apparatus. In support of this, I may refer to the difficulties and hardships of colliery officials and men some forty years ago, when large quantities of water at long distances from the shaft had to be dealt with, and when the only power for working pumping-engines was high-pressure steam, which caused serious trouble, owing to the expansion and contraction of the pipes, steam escaping from the joints, falls of roof, and men having to work for a limited period in an atmosphere exceeding 100° Fahr. The use of compressed air has swept away these difficulties.

In the underground workings of a certain West Riding colliery there are at the present time 28 miles of compressed-air pipes, ranging from 12 to 3 inches in diameter, thirty-two coal-cutters, some of them situated 2½ to 3 miles from the shaft, eighteen auxiliary haulage-engines, twenty-one pumps of various sizes, and ten coal-face conveyors, or a total of eighty-one engines worked by compressed air. These appliances have been the means of doubling the output of coal as compared with former times, of obtaining increased profits, and, what is so vital, of preventing the men from being exposed to the exhausting inconveniences they experienced when steam was used as described. Compressed air does not interfere with the ventilation nor damage the roof of the mine.

After such experience, I believe it possible to drive roads for cold-storage chambers in suitable strata within a reasonable distance above the coal-seams to be worked, in which large volumes of air from the downcast shaft can be cooled and dried by means of refrigerators to a temperature suitable for men to work in. In the same way as it has been necessary in the past, in dealing with an increased quantity of water, to put down more pumps and over a wider area, so refrigerators of greater or less power will have to be erected as required in different parts of the mine. If, for instance, six are not sufficient, then let us put down twelve or twenty, as a suitable and healthy atmosphere is as absolutely essential to the men as is freeing the mines from water.

In order to obtain the best results, careful and extended experiments will be required, to which the actual conditions of a mine offer no difficulties. There is no danger to the persons conducting the experiments, or to the mine, or of any interference with the regular working of the colliery.

I think the time has arrived when the long-anticipated trouble of dealing with a heated atmosphere should be treated in a practical way, and I have confidence that the difficulties will be overcome by the methods which have been successful in working the shallower seams, supplemented by other means which the exigencies of the new circumstances will necessitate.

There are many points to consider, such as the effects of oxidation and compression; driving the main intake roads in suitable strata in preference to coal-seams; using stone or incombustible dust to minimize friction of air and to prevent leakage; the use of small fans in the working-place on the principle of the hand-fan, or the punkah, as used in hot climates. Evidence bearing on this latter point was given by me before the Royal Commission in 1902.

I should have liked to deal with some of these points connected with the important investigation as to the methods of working coal in high temperatures, but, as my notes are already much longer than intended, I will only suggest, for the consideration of the members, that, after the war and when conditions are becoming normal, a Committee, which I might call a Standing Committee, as it should be of a partly permanent character, should be appointed specially to collect information and to inspect works where cooling plants have been in use for many years past, and conduct experiments, if necessary in the Mining Association's experimental tube, with the object of getting all possible data for the assistance of those members who may be called upon to deal with the high temperatures in deep mines. You are aware that for some years past Mr. W. H. Chambers, of the Denaby and Cadeby Collieries, has been devising scientific methods by collecting samples of air in various parts of the mines under his control, and that the information he has obtained has been of considerable use to him in dealing with underground fires and in other ways.

Mr. Blake Walker referred in his Presidential Address to certain collieries in the Doncaster area where already special methods for dealing with increased temperature are in use, and we may therefore assume that this question is of pressing importance.

In conclusion, might I remind you that an eminent writer asked: "May it not be said that the experiments of science are the answers made by Nature to the questions put to her by man?" This remark may for many reasons be considered specially applicable to mining. If the laws of Nature are scientifically and properly studied, it will be found that the difficulties of deep mining are of far less magnitude than at present apprehended, and though we may for a time be perplexed, yet in the long run it will be proved in mining, as in other sciences, that the fault does not rest with Nature, whose wonderful laws appear grander and more marvellous the better they are understood.

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE APPLIED SCIENCE DEPARTMENT OF THE UNIVERSITY OF SHEFFIELD,
DECEMBER 5TH, 1918.

MR. W. D. LLOYD, PRESIDENT, IN THE CHAIR.

DISCUSSION OF PROF. F. W. HARDWICK'S PAPER ON "THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION."*

The PRESIDENT (Mr. W. D. Lloyd): Prof. Hardwick points out that it is necessary that the central bureau mentioned in his paper should receive information from the various branches of the engineering profession as to what facilities at present exist for an education in their particular branch of engineering. Such a survey would be valuable at the present moment, and more particularly to those who are interested in improving mining education. The present position of technical education in mining is far from being satisfactory, and I hope that before the Institution furnishes the suggested central bureau with information on this point such improvements will have been inaugurated that a statement of the position as it exists to-day will be out of date -at any rate, as regards Yorkshire.

Prof. Hardwick points out that the suggestion that a pupil should have one year's experience at a colliery after leaving school, and before entering a University, requires careful consideration. In order to obtain the full benefit of such a course, the student should have an opportunity, during this period, of obtaining a general survey of the work and conditions at a colliery. Presumably, this would have to be under the same firm of which he intends to become a pupil. Mr. Berriman points out that "it must, however, be made possible by allowing time off for attendance at school to maintain the continuity of systematic mental instruction that is essential to the carrying out of the higher educational plan." If the preliminary year is to be regarded as part of the period qualifying the student to sit for a First Class Certificate of Competency, the present requirements of the Board for Mining Examinations would necessitate his being employed in actual practical work underground. If he is to be tied down in this way, it is doubtful whether he would obtain as great a benefit as is contemplated. This raises the point whether or not the present regulations will debar men who have had a public-school education, and who wish to become mining engineers, from doing so, and so deprive the industry of their services. The Coal Mines Act provides that "The owner or agent of a mine required to be under the control of a manager shall not take any part in the technical management of the mine unless he is qualified to be a manager." It is therefore essential that a man who aims at occupying a position in control of mines must first obtain his First Class Certificate of Competency as a manager. In order to do so, he must, in addition to having obtained an approved diploma or degree, spend the greater portion of three years in actual practical work at the working-face and in other parts of the underground workings, or in direct supervision of such work. It would be useful if members would state their views on this point, and also I think some definite ruling should be obtained from the Board for Examinations. For instance, supposing a boy leaves a public school at the age of 18, having passed his matriculation, and then goes for a year to a mine. Let us suppose that he is employed on actual work three days a week, and the other three days is at liberty to go round with the manager, or some other official, so as to obtain a general insight into methods of working and supervision: if a year thus spent would count as six months towards the requirements of the Board, it would also give him such opportunities as are desired by Mr. Berriman. He would then go to a University for at least two years, and obtain his diploma or degree. He would then return to the mine, and if he is prepared to continue the course he would have, say, another year, half in actual work and half in going round gaining experience. At the end of this time he would have left school four years, and supposing that he had not done any actual underground work during his University vacations, he would possibly only have one year's work to his credit with the Board for Examinations. He should, however, then be in a position to be entrusted with direct supervision—at any rate, to a limited extent—and a year spent in this way would at the end of five years provide him with his diploma or degree, one year's actual work underground, one year in direct supervision, and one year spent underground, but not on work approved by the Board. He would now be 23 years old, and if the Board approved of his training he would be entitled to sit for his First Class Certificate. Whilst at the University he would also have presumably qualified for, or obtained, a Surveyor's Certificate.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 94.

I think it is obvious to all that a definite scheme of underground training by a pupil of the sort whose training we are discussing at the moment ought to be arranged, and that a pupil should go through a definite course. The old method of allowing an articled pupil simply to have the run of the pit, without any very defined scheme of training him, is, I think, out of date.

The technical training of boys whose parents cannot afford to give them a public-school education must be undertaken in a different manner. Mr. Berriman makes a strong plea for the revival of the system of apprenticeship in the engineering trades. The system of apprenticeship as usually understood in the skilled trades, and as defined by Mr. Berriman, does not appear applicable to the ordinary rank and file of underground workers. It might and does to some extent obtain in colliery workshops, and it is to the interest of the industry as a whole that steps should be taken to encourage the establishment of a system of apprenticeship for men who wish to become colliery officials. A scheme of this description is in force at Rother Vale and in South Wales, and it would be interesting to learn what results have so far been obtained.

A scheme somewhat on the following lines would seem to be desirable:—Young men of, say, 18 years of age already employed at collieries who, after leaving the elementary schools, have either had the advantage of a secondary education, or, alternately, have continued their education by means of continuation schools or evening classes, and who seem likely to develop into useful officials, should be assisted financially to attend specialized classes either at local Technical Schools or at Mining Colleges for six months in each year of a three-years' course; during the other six months, and during the subsequent three years, they would continue to be employed at the collieries and undergo a definite scheme of training. The colliery company should be responsible for the payment of fees and travelling expenses and a reasonable wage during the whole period of apprenticeship. Separate courses should be arranged for men to specialize in (*a*) mining engineering, (*b*) colliery mechanical engineering, and (*c*) colliery chemical engineering. The best students from these classes should be encouraged by liberal scholarships to continue their education by a full-time course at the Universities, at which also suitable classes—say, on one day a week—might be arranged for those men who have passed through the first course, and for whom it is desirable to provide a continuity of theoretical training until they are 23 years old, and are qualified to sit for their First or Second Class Certificate of Competency.

MR. HARRY RHODES (Sheffield): The system adopted at Rother Vale, to which the President has referred, is also in operation, among others, at Dalton Main Collieries and at the collieries of John Brown & Company, Limited.

Mr. A. **Blenkinsop** (Dalton Main): I do not think the system has been in operation long enough to enable us to express a definite opinion upon it. We started some five or six years ago by getting likely lads to attend night schools. The company paid their fees, put them always "on days," and allowed them to get away early. Two years ago, we went in for the part-time University course. The boys are doing well, and are being trained not only in the workshops but underground. There is every prospect of the scheme being a success.

The **President**: I cannot say that I am, but I have given my opinion.

Mr. J. H. W. **Laverick** (Tinsley Park): It is possible for a mining student to get his Surveyor's Certificate as soon as he is able to pass the examination. Supposing a student starts at the age of 16 or 17: I see nothing to prevent him from getting the Surveyor's Certificate by the time he is 19. As a matter of fact, one of our Tinsley Park boys has done so, which is a clear proof that it can be done. I think that this is a good plan, because it gets the surveying work out of the way while the student's muscles are forming for the practical work at the coal-face that he will have to go through when he arrives at the age of about 19 or 20. I therefore encourage students who come to me to get through their surveying as quickly as possible, to obtain their certificate, and then go straight to the coal-face and get some practical work done.

It is rather appalling that, although we have had before us so many papers on the education of miners and mining engineers, we have not yet evolved anything that may be called a system of perfection. It might not be a bad plan if a few leading men consulted together, as they might then evolve something systematic that would be a credit to the mining profession. I hope that when a system is decided upon it will be one that will not take a student to the University for his whole time. I have found that the best men I have turned out at Tinsley Park have been those who started at the age of 16, who have devoted two (or in some cases three) years to study at the University for two or three days per week, and have put the rest of their time in at the colliery. I have turned out some very good young men, and they are a credit to the place. The system I have referred to is the one that appeals to me, because I do not believe in a student losing touch absolutely with the practical side of his work. The collieries around Sheffield and in South and West Yorkshire are in a position to allow a student to spend three days at the University and three at the pit, and that is a system which I have found to work admirably. The students need not draw the line even at the day classes at the University. They can attend evening classes as well. If a student puts in three years, or even two, straight away at the University, without any colliery work, I am always afraid of his being spoilt for that practical work at the coal-face which every student nowadays is expected to go through.

Mr. F. OXLEY (Sheffield): I consider it of the greatest importance that boys intending to become mining engineers should be educated with that end in view, and should come to the Universities prepared by their previous education to take advantage of the instruction provided; that is, they should come provided with a sound knowledge of mathematics, physics, chemistry, and mechanics.

Secondly, I believe that it is advisable for the boy to spend a year or so at the colliery before commencing his technical education, as by doing so he is, in my opinion, more capable of taking an intelligent interest in the instruction given. If he is the right kind of boy, the practical experience he has obtained will make him take up the theoretical part of his training with a greater zest. If he is not the right kind of boy, he will probably have found the work so distasteful that he will try some new and more congenial field. Another point in favour of this scheme is that the boy's education will be completed at a time more nearly coinciding with that at which he will have to test his prowess in the Home Office examinations.

Prof. Hardwick mentions that there is a variety of courses available for the intending mining engineer. Is not this fact rather confusing to the persons who have to choose for the boy, and would it not be better if standardized courses of instruction were recommended by such a body as, say, The Institution of Mining Engineers? It should be possible for a committee of the Institution, after studying the courses offered by the various teaching institutions, to evolve a course or courses which would have their seal as being suitable for boys intending to take up mining engineering as a profession.

I may be prejudiced, but I believe that the Mining Diploma Course of Sheffield University has a number of good points. The course is one of the " sandwich " type, is of four years' duration, and the students spend six months at the University and six months at the colliery. By this arrangement the student is kept in touch with the practical affairs at the colliery much more than would be the case if he spent, say, three sessions of nine months each at the University. There would be less likelihood, if he took the first-named course, of the youth developing into what practical men call a " theory " man.

Prof. Hardwick mentions another alternative to instruction of the type just mentioned, namely, attendance at evening or Saturday afternoon courses. For courses of this nature to be thorough, they would have to be continued for a considerable term of years—in my opinion for very much longer than is desirable. If the course is not thorough, it will obviously be impossible to get that higher standard of technical knowledge which is so much to be desired. Where it is impossible or impracticable for mining students to take up a diploma course, attendance at part-week courses would be preferable to that at evening or Saturday afternoon courses.

My previous remarks apply more particularly to the education of the articled pupil, but I believe also that the technical training of apprentices, etc. (as defined by Mr. Berriman), would be of considerably greater value if it could be given in the form of day courses in preference to evening courses. I am decidedly of the opinion that instruction of an elementary rather than of an advanced nature should be given in evening or Saturday classes. It is impossible, without extending them over a very long period, to give a *thorough* advanced course.

Mr. G. Blake Walker (Tankersley): I am quite in accord with a great deal that has been said by Mr. Laverick. We must remember that we have to deal with a great variety of young men—men whose ambitions vary a great deal, from the highest posts to very humble ones—and we cannot expect more than a certain proportion to attain that degree of culture and training which we all admit is a thing to be desired. We have to contend practically with a certain amount of—if not opposition, at any rate inertia—on the part of the workman, who do not wish to see a social class superior to their own put in positions of administration and responsibility. The workmen have themselves taken certain steps, although only tentative steps, to qualify a certain number of men from their own class to take the highest positions.

In various Continental systems it is often found that the preliminary course has been secondary to the higher scientific or University course. This is probably the case at the older Universities as compared with the more modern institutions. We require very broad-sided men in high positions for the management of collieries, which are now becoming very large and important concerns; and matters which are not, strictly speaking, technical, become of ever greater importance as the years roll on. We want a high degree of culture, not only in the things which we have perhaps been accustomed to regard as such, but in such wider fields as economics, which are now becoming a preponderating occupation for the minds of all those who have the administration of collieries. There is a very wide field of technical knowledge which is expected of the colliery manager, and to which in the past he has been for the most part unequal. When a man is called upon to deal with an important proposition in organic chemistry, he often feels that he is badly equipped, because he was not trained in that very abstruse science, and all he can do is to depend upon subordinates who have specialized in that branch of learning. Then, again, with regard to machinery, which is becoming more and more essential in the underground management of pits, a man requires a training not only as a mining engineer but as a mechanical engineer. Mr. Berriman clearly had in mind throughout his report the shop apprentice, who becomes, after he has been through the shops, a foreman, probably rising in importance with regard to the workmen. But the proposition which the Institute has to consider is a very different one. I believe the position of the articled pupil is a very valuable one indeed in the mining calling, but it is not so universal and so beneficial perhaps as in mechanical engineering, where a youth is engaged for a number of years in the same works. I am convinced that the mixing of the practical with the theoretical training is very advantageous, as one is fostering the other all the time. A boy can then learn to apply to his daily work in the pits the theoretical instruction he receives at the Universities, and if he does so he becomes the most useful sort of mining engineer that we can have. But a great deal depends upon the individuality of the pupil. We shall not succeed in making every young man take advantage of his opportunities. The pupil must become as broad as he possibly can, and the wider his general knowledge the better it will be. I do not think we have quite achieved all to which we have looked forward. We have a class of men on whom we largely depend for officials, and who would be the better for being better instructed than they are at present. That class is an increasing one, but one of the practical difficulties with which we all have to contend is the question of remuneration. The least scientific work is, in mining as in many other callings, the best paid. When we can give a young man an object for which to work—when he can look forward to earning a respectable living in middle life—then I have no doubt a number of people will offer themselves, from the public schools or elsewhere, for the mining profession; but when we can hold out nothing beyond the position to which the ordinary miner could expect to attain, I am afraid that the inducement to young men to enter the mining profession will not be very strong.

Prof. L. T. O'SHEA (Sheffield University): I agree with Prof. Hardwick that the provision of a central bureau as proposed by the Engineering Training Organization is of primary importance. There is at present no central authority to which a parent or a headmaster of a school can turn for advice. Those in the profession probably know the best avenues by which a youth can be trained for it, but one who is outside is usually dependent on the advice of his friends, which may or may not be reliable.

The object of the discussion, however, is to obtain the views of the mining profession on the necessary qualifications and the best method of obtaining them, in order to give information to the Engineering Training Organization for its guidance.

It is difficult to decide this question from the papers and discussions published in the *Transactions*, as the opinions expressed differ very widely. Training in the mining profession differs from that in other branches of engineering. It is controlled largely by the statutory qualification required for the First Class Certificate of Competency. This qualification makes no distinction between the mining engineer and the colliery manager. Does it not seem desirable, therefore, that the Institution as a whole should decide whether the training necessary to qualify for the First Class Certificate of Competency is sufficient for a man who hopes to undertake the responsibilities of the development of large properties and the control of large amounts of capital?

Another point of difference is the position of the articled pupil. The ultimate object of the pupil articled to a mining engineer is to obtain the First Class Certificate, to achieve which he has to comply with the statutory regulations as regards practical experience. It would appear that he belongs to both classes defined by Mr. Berriman, namely, "articled pupil," whose object is to obtain an insight into the general organization of a colliery and its various departments, whilst legislation compels him to acquire a definite standard of practical experience, which brings him under the class of "apprentice" as defined by Mr. Berriman.

There is also the worker at the face to consider. It is within his powers to obtain the First Class Certificate, and having obtained it, he and the articled pupil with the same qualification enter the same field, namely, as men qualified by statute to undertake the management of a colliery.

It seems necessary, therefore, to decide how to ensure that the best and most capable of these two classes should rise to the highest ranks in the profession. If it be decided that no further training is necessary except that obtained by experience in colliery management, then the problem is reduced to considering whether the educational training at present offered in Universities and Technical Schools requires any modification, and whether the system of practical training of articled pupils can be improved. If, on the other hand, it be decided that the more capable and intelligent of these men should be encouraged by a higher training than that required to pass merely the examinations for the First Class Certificate, the problem is what that training is to be, and how it is to be incorporated into the present educational facilities both academical and practical.

This is a general aspect of the problem which in my opinion requires to be settled by a general consensus of opinion on the part of the profession. There are also important points of detail, but these are different for the articled pupil and the worker at the face.

With regard to the articled pupil who has had a public-school or secondary-school training, various points arise:—

(1) To what extent can the school education of these boys be directed as a preliminary training for entering the profession? Boys intending to enter the army and civil service have special attention given to them in the later stages of their school career to this end, and it is not too much to suggest that special attention should be given to physics, chemistry, and mathematics in the latter years of the school course in the case of boys who intend to enter the mining profession.

(2) Whether a boy intending to enter the profession should be encouraged to matriculate before leaving school so that he can, if he so desires, proceed to a degree in mining engineering? Whilst I do not know that the degree in mining is essential, so long as the training is undertaken, it is important to remember that a pupil cannot proceed to a University degree unless he has passed the matriculation or some equivalent examination, and it is desirable that this should be done on leaving school.

(3) A most important point is the relation between practical experience at collieries and academic studies. There is little doubt that in all applied studies the sooner the pupil gets into contact with the industry he intends to enter, the better; the workshop is an excellent training school. There is considerable difference of opinion as to how these are to be co-ordinated. Is it better that a youth should spend one or two years entirely at a colliery before taking up his academic studies, or should he at once combine works' practice and academic studies on entering his pupilage? There is much to be said for both, but of the two I think the former has distinct advantages, especially if during that period the pupil attends evening classes and if the academic course which follows is combined with practical training at the pit.

At some of the Universities diploma courses are arranged on the plan of six winter months given entirely to University work and six summer months given to work at a colliery for three or four years, and I feel that much good would result if the articles of a colliery pupil included a condition that he be allowed the time necessary to follow this course. Some advocate that it would be better if a pupil spent his whole time at the pit and continued his academic studies by means of evening classes—at all events, for some three or four years before joining day classes at a University. I doubt whether this is the most profitable course to be taken by articled pupils. Day study is much more profitable than evening study, and it would be for the good of the profession to encourage day work at the Universities and Technical Schools.

The case of the worker at the face is different. He obtains experience of work underground, and except for officials this may or may not be limited in its scope. His education is carried on in the meantime by means of evening classes, in which the subjects are to a great extent limited to cognate technical subjects. He probably will rise in the profession through the stages of deputy and under-manager. In his case it is first necessary to ensure for him progressive training up to the time of his becoming a deputy, and during that period, by a system of scholarships and other financial assistance, to afford the most promising of these students the opportunities for higher training in the scientific branches of study cognate to the profession.

This Institute has under its consideration a comprehensive scheme of mining education. It has adopted proposals for the advancement of the education of the deputy and under-manager, and is now engaged in extending the scheme to the training of colliery pupils and such mine officials as are able to profit by more advanced studies. How the scheme is to be extended to the higher training of a mining engineer is under consideration. To a large extent this involves the question of scholarships, which it is the object of the Engineering Training Organization to foster. If students from the operative ranks of life are to take advantage of the higher training, they will require substantial financial assistance, considerably greater than it appears necessary or desirable to offer to youths of 16 to 18 years of age. Scholarships of two kinds would appear to be necessary—(1) of a value, suitable for boys leaving school, from £30 to £50 per annum, which would cover tuition fees and books, and cover travelling expenses; and (2) of higher value, for the student from the operative class, which would afford some degree of maintainence in addition to tuition fees. To these certain restrictions could be attached, with respect to the age and financial position of the candidates. On some such lines as these a scholarship scheme might be formulated. In many of the education schemes under the County Councils there are certain scholarships that can be obtained by the boy leaving school. These, however, are not generally for mining students alone. It would, I think, be advantageous if mining scholarships were offered. I know of none on the higher scale. The question as to who should provide these scholarships is an important one. Personally, I think it would be in the best interests of mining education that the industry should do so.

Various schemes have been put into operation and are worked with various degrees of success. To get a scheme applicable to the whole country is hardly possible. What is wanted is to arrive at general principles which should form a foundation on which a sound system of education can be built, and leave the actual means of carrying out the plan in each different mining district with its own organization. If this results from the discussion, as I hope it may, the Council of The Institution of Mining Engineers will be able to respond to the Engineering Training Organization in its desire to forward the training of mining engineers.

DISCUSSION OF MR. W. COLQUHOUN'S PAPER ON "SOME ECONOMIC CONSIDERATIONS IN COKE-OVEN PRACTICE."*

Mr. D. BAGLEY (London) wrote: In contrasting British with American practice, Mr. Colquhoun states, *inter alia*—

> "The resulting large output of coke yields a quicker return on the capital outlay, but, as may be expected, at the expense of part of the bye-products. It is estimated that the recoverable bye-products are reduced by 20 per cent. for tar and benzol and 10 per cent. for sulphate. Although the value of the bye-products sacrificed is of small importance compared with the value of the coke, this waste does not commend itself."

This admittedly general comparison implies that by carbonizing at a higher temperature a superior capacity is attained—with better fiscal results—apparently neutralized by the alleged sacrifice of volatile products, which condemns the practice upon economic grounds. According to my observations in the United States of America, I am not prepared to accept this statement regarding alleged wastage of bye-products in its entirety; moreover, the comparison completely ignores, or fails to give due credit for, the superior yield and quality of merchantable coke, and the largely increased volume and thermal value of the surplus gases. My opinion is that the advantages of rapid carbonization outweigh any possible defects. Some years ago we succeeded in reducing the coking period to 24 hours—equivalent to approximately 70 minutes per inch of width—without loss of liquid or gaseous residual products: on a 16-hour basis the decline in ammonia (slight) and tar is accompanied by advantages which my contrast will disclose more than compensate for the decrement. High constructional costs, with the imperative necessity of bringing the capital expenditure per ton-year into line with the European basis (it will have been observed that the values of bye-products in Europe and the United States closely correspond), dominated American practice. Beyond this, a hard coke is indispensable for

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 61.

American conditions. High constructional costs obtain with us, and are likely to continue, and hard coke is a condition precedent to true economy in the furnace. If we assume the substantial accuracy of Mr. Colquhoun's comparison, without giving credit for the advantages admitted, we convict the United States—the largest producers of retort .coke—of a wasteful practice. I am convinced that such condemnation is unwarranted, and that their practice will contrast not unfavourably with our own when all the factors are taken into consideration. I submit that our iron and steel industries will demand that future excess capital charges shall be neutralized as far as possible by increased efficiency in the production of coke; thus, if fifty rapid regenerative ovens will give a capacity equivalent to one hundred of the normal type, adherents to the latter must be able to offer proof that the value of their gaseous and liquid residuals will provide a surplus, in comparison, sufficient to offset the lower capital charges pertaining to the rapid type, whether the coking period is 24, 20, or 16 hours, and that the quality and quantity of merchantable coke shall be at least equal to that produced at the higher temperatures.

Coke.—The importance of coke hardness, appreciated by all the well-known authorities, and recently exhaustively examined by G. D. Cochrane, is admitted. Moreover, I believe it is agreed that the " hardness " is generally increased by an enhanced carbonizing temperature. In transit, hard coke suffers less, and the quota available for the furnace is correspondingly increased; in the furnace, it offers a greater resistance to the action of the ascending gases, and a relatively larger quantity of carbon passes to the reduction zone. Hard coke infers free driving, a relatively lower consumption, an even quantity of iron, and a regular and consistent volume of gas for stoves, boilers, and power purposes; the reverse applies equally to soft coke. It is true that a coke suitable for furnace requirements is producible on a 32-hour basis, but I maintain that the consumption varies inversely as the hardness of the coke, and that a " rapid " coke is more economical from every standpoint.

In the vicinity of Sheffield, three grades of coke are in use, namely, "furnace," "foundry," and "steel." The latter is usually carbonized in the beehive oven, and, disregarding for the moment the relatively purer fuel initially employed in its manufacture, hardness is the preferable characteristic. Similarly, foundry coke from beehive ovens is still preferred by many users. If we exclude any reference to relative size, which, after all, is not an insurmountable obstacle, my impression is that it is possible to satisfy the exacting requirements of individual users by a " rapid " coke in the production of which the valuable bye-products have been isolated and recovered.

The gradual exhaustion of our better qualities of coking coals must lead to our reliance upon less valuable varieties. I suggest, from the coke aspect, that inferior fuels generally benefit by more rapid carbonization. Take, as one example, the Pittsburgh Seam, which now without admixture provides a suitable metallurgical fuel able to support a high burden driven at a maximum rate. This coal when carbonized in the retort oven at what is now characterized as a normal speed yielded an inferior coke.

With a high carbonizing temperature, and under certain well-defined conditions, some coals now regarded as unsuitable for the production of coke may be successfully utilized if admixed with coking varieties.

It should be borne in mind that the function of the oven is to produce the largest possible yield of metallurgical fuel of the highest quality, and that true efficiency is measured by the quantity of coal—as distinct from coke—which is consumed per unit of metal. Bye-products must remain secondary, although economy rightly insists that the yield and quality shall be as high as is consistent with the primary objective. The rapid oven achieves both these objectives.

Tar.—I am willing to accept a reduction in yield equivalent to 20 per cent. as an extreme limit for the 16-hour oven. I have previously stated that we find no reduction on a 24-hour basis, and we may expect a gradually increasing diminution to the lower limit, due to the increased carbonizing temperature. It is unnecessary to discuss the divergence from normal practice: decomposition of some of the constituents is, of course, a feature, with deposition of carbon—an advantage from the coke aspect, and a largely increased yield of gas of superior thermal value to that usually accepted as normal in this country.

Benzol.—Under rational operative conditions when carbonizing on a 16-17-hour basis, the content of benzol and its homologues in the gases evolved—as distinct from a crude product containing varying percentages of wash-oil—does, according to my observations, very closely approach the results obtained in British practice. According to a series of tests conducted in 1913 and 1914, the content ranged from 2 to 3·25 American gallons per short ton of 2,000 pounds of coal calculated on the dry coal, the superior limit being achieved with a coal containing 32 per cent. of volatile matter charged with 6 per cent. of moisture, the inferior with a dryer coal, unwashed. When equated to our standards for similar coals, I submit that the alleged loss of 20 per cent. disappears, and we arrive at almost identical results.

Certain practical determinations were made in 1911 with the object of ascertaining the effect of increasing temperature upon the actual yield of benzol. With the advent of our 24-hour oven in 1913, carbonizing 12 tons, we found no decrease. We have since been able to determine the conditions which ought to obtain to secure the full yield from the rapid oven. The results I have quoted confirm my view that Mr. Colquhoun's estimate is opposed to actual facts. Obviously, the quantity isolated and recovered depends upon the complete process employed and the apparatus utilized, and, in this respect, I could mention British plants where the recovery was only 60 per cent. of the attainable yield. If Mr. Colquhoun's statement were limited to a period anterior to 1914, I might be disposed to accept his figure; but, with improved conditions in the United States, this no longer holds.

Following research, my impression is that it will be possible to increase the volume of liquid hydrocarbons suitable for automobiles from the coking process, and to provide a product possessing in greater degree those properties which are essential to meet the demands of the motorist—and, I might add, the airman—whilst retaining the rapid oven.

Ammonia.—When contrasting British with American practice, let us bear in mind an important fact. If an oven be forced down from 24 hours to 16 hours, the volume of gases evolved is increased by 75 per cent. Unless the condensing and recovery plant be expanded proportionately, a reduced efficiency is a foregone conclusion; on the other hand, complete expansion may involve unremunerative capital expenditure, and a basis has to be established. But the decrement in ammonia yield cannot be charged entirely to the enhanced carbonizing temperature. Observed yields of mine ranged up to 25 pounds of sulphate per short ton. I should be prepared to admit a deficiency not exceeding 5 per cent. as representative of American practice in contrast with ours; but American expert opinion is not, and will not rest, content with any divergence from standard experience. They are striving to achieve better results; and so are we.

In this country, we must shortly face synthetic ammonia, producible at a cost permitting its sale well below what has hitherto been regarded as a fair value for the ammonia. I came to this conclusion in 1913 when discussing Haber's process, and have since endeavoured to check his costs from known data, assuming an average yield over the catalysts, and I have no reason to modify my conclusion, which, I believe, is supported by independent investigators. A relatively high hydrogen content in the gases with increased surplus power, features of the rapid oven, may—if we take a futurist's view—prove of value.

Surplus Gas.—According to my observations in America, the gas yield on a 17-hour basis per 2,000 pounds of fair quality coal averages from 12,500 to 12,900 cubic feet : the equivalent of our ton standard is 14,000 and 14,500 cubic feet respectively. Following the abstraction of benzol, the average thermal value of the gas over several months was 540 British thermal units. Taking Mr. Colquhoun's basis, namely, a surplus of 5,500 cubic feet at 450 British thermal units, and contrasting this with a surplus of 7,000 cubic feet at 540 British thermal units, there is an excess of heat (surplus to the oven requirements) equivalent to an increase of 2,900 cubic feet above the British standard.

Whilst gas of the standard referred to falls, I believe, within the specification now acceptable for public purposes, I propose, in examining the revenue sheet, to assign a fuel value of 4d. per thousand cubic feet of gas of 450 British thermal units. If we were to base our estimation on what, for example, Sheffield might pay for a gas of the rapid quality, the result would be, of course, considerably better.

The True Contrast.—If the figures I have previously mentioned be accepted, they will be applied to the bye-product revenue from 100 tons of coal. We will assume the normal British yield to be 5 per cent. of tar, 1·18 per cent. of benzol, 1·26 per cent. of sulphate, and 550,000 cubic feet of surplus gas, and, in contrast, the American yield to be 4 per cent. of tar, 1·18 per cent. of benzol, 1·20 per cent. of sulphate, and 840,000 cubic feet of surplus gas. Assigning the values of these respectively as 35s. per ton, 1s. per gallon, £12 per ton, deducting acid and other expenditure, and 4d. per 1,000 cubic feet, there is a difference in favour of the American practice of £2 8s. Upon the like basis, taking Mr. Colquhoun's figures, the difference is in favour of the British practice to the extent, however, of only approximately £1 9s. I have not allowed anything for the superior yield and quality of the coke, nor have I taken into consideration the reduced capital, upkeep, and labour charges applicable to the rapid oven. In any case these will exert a preponderating influence.

The type I am now interested in is a 16-22-hour oven, a perfectly flexible unit, containing a charge of 12 tons of coal. We are perfectly familiar with the upper limit according to European practice, and with the lower limit according to American practice. Fortunately, our direct process of ammonia fixation, in which the hot gases are brought into direct contact with the condensing medium, permits this flexibility to be attained without recourse to additional or spare units for dealing with the excess on the lower period of carbonization.

According to a recent communication, Mr. W. H. Blauvelt, of the American Semet-Solvay Company, states that—

> "*From the point of view of American metallurgical practice,* the American ovens [that is, ovens of the rapid type to which I have referred] are superior to those of Europe. The points of superiority are larger units, and larger output per unit, and the greater extent to which labour-saving machinery has been introduced. The modern American oven will carbonize more than 20 tons of coal per day, and, contrary to the European idea that slower operation is necessary to conserve the plant, this rate of operation, with only current repairs, can be maintained for an indefinite time. There are a number of plants in different parts of the United States, built 16 or 18 years ago, which are more efficient to-day than in the first year of operation."*

This statement is in complete accord with my views, as already expressed, and my hope is that British metallurgical practice will not hesitate to adopt and improve upon a process unanimously endorsed by expert experience in the States. I believe I was the first to introduce the rapid oven in Europe, and I did not do so until I was satisfied that it possessed superior merits, and that its construction was practicable. Mr. Blauvelt continues: "Since the bye-product oven was brought to America from Europe, it has been rapidly improved." I concur, and the credit is due to American engineers, who, despite largely increased constructional and operative charges in comparison with ours, have evolved a type permitting equality—if not superiority—from the revenue-bearing aspect. It is for us to build upon this foundation, and so to support British metallurgical practice in its efforts to regain and retain its position in the world's markets during a period of intensified competition.

Mr. W. Colquhoun, in reply to the discussion, said: I am glad that the advantages of limiting the moisture in the coal are so strongly supported and supplemented by Mr. Porteous. A lower moisture than that only too usual will increase the return on capital by shortening the coking time, and improve the yields of bye-products, as well as (according to Mr. Porteous) increasing the yield of coke itself.

Mr. Foxwell asks whether we are "entitled to say that the water evolved from coal on distillation" is "combined water." No, we cannot say that. I have fallen into the common error of speaking of combined water when I mean the formation of water which attends the carbonization of coal. I have no doubt that, this correction being made, Mr. Foxwell will not question the moderate amount used to illustrate my argument, namely, 4 per cent.

Mr. Foxwell doubts whether horizontal flues are coming into favour again, on the ground that in America (and perhaps also features of the rapid oven, may—if we take a futurist's view—prove of value.

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Mr. Foxwell doubts whether horizontal flues are coming into favour again, on the ground that in America (and perhaps also in England) a much larger number of vertical flues are being built. If this is so, it is because the vertical-flued oven is cheaper by 10 to 15 per cent. than the Semet-Solvay oven. But although the vertical-flued oven is cheaper in first cost, I think that the ultimate cost—the prime cost per ton of coke, including repairs, over a period of, say, 10 years—is in favour of the Semet-Solvay oven.

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* *Trans. Amer. Inst. M. E.*, 1918, vol. lvi.

Mr. Foxwell thinks that an equal distribution of the heat in horizontal flues is impossible. His conception of such a flue, with a burner at one end and a constantly decreasing temperature throughout its length, is somewhat crude. The fact is that the whole volume of burnt products, totalling over 900 cubic metres per ton of coal carbonized, in sweeping through the flue, maintains a temperature practically uniform throughout its length.

Mr. Blyth suggests that the words "temperature sufficiently uniform" would be more exact than "temperature quite uniform," and I think he is right. Referring to the flue temperatures recorded by Mr. Blyth, there is no call for so wide a difference in the temperatures at opposite ends of the flues. Temperatures taken on 2nd December, 1918, in No. 4 flue at Hoyland are as follows:—

	Burner end. Degrees Cent	Opposite end. Degrees Cent.
Oven No. 1	1,130	1,140
	1,130	1,120
,, 5	1,140	1,130
	1,150	1,140
,, 6	1,040	1,050
	1,030	1,050
,, 8	1,030	1,040
	1,050	1,050

It will be observed that the temperatures are frequently higher at the far end than at the burner end.

The proof that the temperature is "sufficiently uniform" in these ovens lies in this, that of seven plants in Durham and Yorkshire the standard 7-foot ovens coke 45 tons (the lowest figure) to 48 tons (the highest figure) of dry coal per oven per week. This is the average capacity over a term of years.

Mr. Foxwell questions the statement made in the paper that the decomposition of the gases that are evolved is inappreciable below 870° to 900° Cent. As a coke-oven man, I was thinking of the decomposition of ammonia and benzol vapours, and not of the gases. The subsequent sentence made it plain that decomposition of these vapours is prevented in the state of dilution in which they occur.

With regard to the time required to stamp a compressed cake for 12-ton ovens—24 minutes—Mr. Blyth states that at Thorncliffe the time taken is 32 minutes. He will admit that up to this date two-thirds of the coal is not washed, and is artificially wetted for compression; also it is not crushed as fine as it should be. I hope he will succeed in reducing the time.

With regard to the number of men required to work the feed-table and conveyor, in Durham several plants similarly laid out are operated by one youth per shift, as I have stated.

With respect to the 12-ton oven, Mr. Blyth will not, of course, come to a conclusion until the washery is completed at Thorncliffe, nor expect that the high narrow charge will lead to broken cakes, or necessitate undue tapering-off at the ends. He suspects that the longer travel of the gas in high ovens may affect the yield of bye-products, but the yields obtained at Hoyland are not lower than those obtained in neighbouring ovens of smaller size. Were the yields higher from the old design of ovens only 6 or 7 feet high than in the more modern 8-foot oven?

Mr. Marr maintains that a duplicate set of standpipes, to be put in action simultaneously during the first 12 hours of the coking period, is called for by a study of the volume of gases given off during that period. I believe he is right, and that it would increase the yield of bye-products by quick removal of the gases. All that stands in the way of the development of his idea is that coke-oven contracts are settled on strictly competitive principles, which frequently bar the way to improved ideas.

Mr. Middleton remarks that "there is one great advantage which the vertical-flued regenerative oven possesses over the horizontal-flued oven, namely, the quantity of spare gas which it produces." Mr. Middleton is not comparing like to like, but the waste-heat horizontal-flued oven with the regenerative vertical-flued oven. Horizontal-flued regenerative ovens give as much spare gas as any vertical-flued oven.

Mr. Middleton also says "at many coking plants compressors have been discarded, and hand-charging has been reverted to," and that "it is very doubtful whether there is much gain when using a good coking coal." That question can be decided by trying simultaneously a compressed against an uncompressed charge in the same battery. If there is no gain in compression, the matter is settled. Some who have discarded their compressing plant have been the victims of cheap and unreliable machines imported from Germany, or have not taken steps to maintain them properly.

In reply to Mr. Bagley, I think that a practice that may be legitimate in America may be wasteful here. The resources of coking coal in America must appear to be inexhaustible to the present generation of Americans, while ours are rapidly diminishing. Again, the value of the coke and bye-products, in relation to the value of the coal, may justify a wide difference in the practice of two countries. I venture to submit that, on strict economic grounds, if due consideration be given to all the circumstances, the interests of this country demand that our limited resources should be turned to the best use; we cannot sacrifice any fraction of the bye-products for the sake of a larger yield of gas (obtainable in any case from the less valuable non-coking coals).

The reduced yields of tar and ammonia were noted in America when silica construction and quicker coking was introduced, and the figures are supported by several observers. Mr. Bagley admits a reduction in the yield of tar—to the advantage of the yield of gas—and I know of nothing that supports his opinion that the analogous product—benzol—escapes a similar reduction.

It is admitted that a greater output of coke reduces the cost of operation and repairs and yields a quicker return on capital. We cannot in this country expect, however, to equal the American output of coke per unit, because, in the first place, they have coals, or mixtures of coals, which produce good coke structures, usually obtainable in this country only by compressing; this limits for us the height of the oven, or weight of charge. In the second place, while their coal is unwashed, and therefore relatively dry, all our coals are washed and contain 11 per cent. and upwards of water, the presence of which lengthens materially the coking period. American conditions of operation are therefore not entirely open to us, and no comparison such as that offered by Mr. Bagley can be made.

The heating flue temperatures in American ovens, while higher than ours, are not substantially higher than some of ours, and I have observed that when using fireclay bricks the coking time is not reduced to anywhere near the American standard by raising the temperatures to equality with those in America. I infer, therefore, that the larger output obtained from the American unit is attributable to the high heat-conductivity of silica material, and other causes already mentioned, rather than to high temperature merely, as Mr. Bagley implies.

In qualification of some of Mr. Bagley's statements, I cannot think that quicker operation will necessarily increase the yield of coke, and it is not always that it will make a better coke, but sometimes the contrary, for one of our best-known cokes from washed and compressed coal is rendered small and fingery by forcing the rate of coking. Again, references to 16, 20, or 24-hour ovens convey no meaning if the width of the oven and the moisture content of the coal remain unstated.

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APPENDIX IV.—Descriptions of Various Coke-oven Plants.

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THE NORTH STAFFORDSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD AT THE MINING SCHOOL, STOKE-ON-TRENT, DECEMBER 9TH, 1918.

PROF. SIR JOHN CADMAN, K.C.M.G., D.Sc., PRESIDENT, IN THE CHAIR.

DISCUSSION OF PROF. F. W. HARDWICK'S PAPER ON "THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION."*

The PRESIDENT (Prof. Sir John Cadman, K.C.M.G.): The paper covers a wide range. It deals with two sides of the subject—with the general scheme of education, and with the point raised by the Engineering Training Organization, which is the means by which members of the general public can enter the profession. The mining profession, however, is rather different from the ordinary engineering branches: it is very largely hereditary, and of necessity must be more or less so. It is, moreover, rather a close corporation—wrongly so in my opinion—for there should be opportunity for everyone who has the ability and a liking for the mining profession to enter it. My experience is that many boys from school who have ambitions in the direction of coal-mining, after their first trip down a mine, decide to have nothing more to do with it. One has thus to be brought up in the environment of mining in order to know the charms and attractions of the profession.

This training of students in coal-mining is by no means a simple problem, as, indeed, is indicated by the great diversity of views expressed in the various papers referred to by Prof. Hardwick. Almost every mining professor or lecturer has felt it incumbent upon him, at some time or other, to outline and justify a particular curriculum upon which he was working, and not infrequently has found assistance and stimulation by presenting his views in the form of a paper, thus securing a discussion which has enabled him to crystallize his ideas and to make such alterations as public opinion, expressed by this means, might suggest. Generally speaking, there appears to exist much confusion as to the best lines upon which mining students should be educated—confusion, which, on analysis,

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does not in reality exist. This confusion has arisen because the education of students in coal-mining has been looked at as a whole, instead of being divided into the various grades in which the personnel of a colliery staff must inevitably be graded. In my opinion, these divisions might be grouped as follows:—(1) The mass of underground workers aspiring to become underground officials; (2) managers and under-managers; and (3) general managers and mining engineers.

There should be ample opportunity by scholarship and learning for a free passage from the minor grade to the major grade, but on general lines the training is very different. The training in grade 1 commences in the elementary schools, and passes to the night schools and County Council evening and Saturday classes, from which courses there should be little or no difficulty for an average candidate to qualify for the post of fireman, overman, under-manager, and, possibly, manager. The second grade should require fundamentally different treatment, for it should embrace more advanced application to the sciences connected with mining. In this case the higher courses of the County Council and the Technical Schools form the track along which the greater portion of these students should pass. In the third grade the Public Schools and Universities, or the Technical Colleges, form the channel through which these candidates are destined to go.

The elementary training for those entering the University or Technical College is not sufficiently recognized. More attention should be given in the schools to preparation for matriculation, and classes in the minor grade to which I have referred should be constructed to lead to matriculation. To examine a candidate for a University scholarship as to his proficiency in the art of mining as a qualification to enter upon a University course is unsound. The candidate's educational framework should be tested, and not his knowledge of the practice of his ultimate profession. It is possible for anyone responsible for the educational curriculum to substantiate his views for that particular grade in which he is working, and when an attempt is made to discuss the three grades as one, confusion must inevitably result. In all such discussions there is a tendency to be blinded by the present, instead of boldly probing into the future. The young mind is the one that has to be educated, and it is to that end that the educational gun should be pointed. It is, perhaps, disquieting that we cannot see whether we have hit the target. Posterity alone can decide.

Mr. E. B. WAIN (Whitfield Colliery): It appears that Prof. Hardwick has not taken note of the future of education as it will be decided by the new Education Act. The question of matriculation and much of the preliminary training of prospective mining engineers and colliery managers might, with very great advantage, be dealt with by means of the tuition that would be set up under the new Act.

In the past the training of those seeking to qualify as colliery officials and colliery managers has been too largely governed by the hard and fast rules laid down by the Coal Mines Regulation Act. Take the question of practical experience, which appears to most of us the one essential factor in the education of a colliery manager: a man might have had no practical experience whatever in what was, perhaps, the most important branch of his future work, that of the control and direction of labour. His five years' experience might have been gained in pushing wagons about, or in some other subordinate capacity, but that experience is counted as higher practical experience than that of the pupil or apprentice who has had full opportunity of making himself conversant with the whole details of the operations of mining above and below-ground. The question of what is " practical " colliery experience requires to be more broadly defined.

So far as the future is concerned, it appears that under the new Education Act it will be possible for every lad of merit to reach any sphere of education and to enter any profession—to pass from the elementary to the higher school, and thence to the University—and in that connexion the old scheme of education will be practically revolutionized. I think, however, that it is of the greatest possible importance that some general scheme of sound preliminary education for matriculation and for admission to the higher branches of education should be adopted. In every profession a standard of general education that has no direct bearing on the particular profession itself is necessary, and if in the course of that training a lad shows merit, he can then pass on to the details of the profession which he wishes to adopt. The great thing, after all, is that the foundations shall be well laid, and a good groundwork in general rather than specialized education will be an important factor in the earlier training of those destined for any profession.

Mr. John Gregory (Sneyd Colliery): Since I entered the mining profession the whole question of the education of the mining engineer has been revolutionized. The various University courses devoted to mining and allied subjects and the County Council mining classes were not then in operation. The routine course was for a pupil to be articled to a mining engineer at a colliery, or for a youth to work his way from actual work underground, through hard home study, with very little assistance, until he obtained his certificate and became qualified as an under-manager and then as a manager. The need for increased education is evident to anyone who looks at a modern colliery as compared with a colliery of 20 years ago. Nearly every branch of practical science is drawn upon to-day to assist the manual labour of extracting the coal. Like most people connected with collieries, I have my own ideas as to the most favourable course for a student to take: first of all, the foundation-stone is a good education on broad lines, in which an insight is gained of the principles of physics, chemistry, and mathematics. It is necessary to have a good general grounding, because in a man's after-life he will have to deal with many problems: he will have to write many letters; he will have to understand legal documents; and he will have to do many things that make a sound general education essential. I am in agreement with the President that in the early days specialization on mining subjects should be avoided. When a student has obtained a good grounding in the sciences, he can soon pick up the application of those sciences to his profession in his later education.

Prof. Hardwick raises the question whether the student should have any practical mining experience before taking up his colliery course. There are arguments on both sides, but my idea is that he should possess this knowledge. Unless he has had some little experience, a student will be unable to take full advantage of the instruction given to him; I also support the " sandwich system," for, unless the scientific training and the faculty for observation in the pit go hand in hand, the student cannot take the fullest advantage of either. There is no doubt that in that respect the County Council classes in the various districts are a great advantage, but I think they might be still further extended. They cater chiefly at the present time for the men who spend the whole day in mining, and who have only the evenings available. I consider the North Staffordshire district is of sufficient importance for day classes to be instituted as well—so that a student may spend a certain number of days in the week at practical work and the remainder of the week in dealing with the theoretical side of mining. It is also important, apart from all the scientific training a man may get, that he should have the opportunity of negotiating commercial problems and of handling labour. All the sciences and all the training in the world will not fit a man for a responsible position, unless he has " common sense," and common sense can only be developed by experience.

Mr. J. T. STOBBS (Principal of the Stoke Mining School): I welcome this discussion of the question of education by mining engineers, because, as a rule, the subject is chiefly discussed as between teachers. The paper starts with the stage a little earlier than that of the apprenticeship of a pupil, and it deals—I think unfortunately—with a rather circumscribed type of mining engineer. Sir John Cadman has referred to the fact that the profession is largely hereditary. Fortunately, that is the fact, and I think everyone here will agree that nothing in the education of mining men is really of such value as being brought up in a mining atmosphere at home. This is the finest asset in a mining man's training or education; and I do not hesitate to call it "education," because it is education essentially of the right kind. I heard the Master of Balliol recently give one of the wittiest and wisest definitions of education, which I venture to repeat here. "Education," said Mr. A. L. Smith, "is what is left after a man has forgotten everything that has been pumped into him." In these days information soon becomes out of date, but by its means the student's faculties are sharpened and his outlook broadened. I was glad to hear previous speakers insist upon the necessity for a broad basis for education. At the outset when a boy goes to school the object is to make a *man* of him. If you start to make him a mining engineer, it is quite possible you may be spoiling good material for a poet or a parson. Later on, in any case, there is the possibility of a youth changing his profession. Give a boy a liberal education—I do not say mathematics or physics or chemistry or Greek or anything in particular—give him what is implied in a liberal education. Let him go to a good secondary school, and thus give him a good start. At the age of 17—certainly not later than 18—send him to a mine and let him obtain real knowledge of the underworld and its inhabitants. He may, simultaneously, or later, take an advanced course of instruction in the fundamental sciences of the business. In connexion with most mining schools syllabuses are drawn up, but they are only education on paper. The desideratum is a school or department where there is a real live head, and then it does not matter so much about the syllabus. The youth would have infused into him an enthusiasm for work, his eyes would be opened to the possibility and methods of research, and he would generally be made to use his own faculties. Such a man is bound to be a success in after-life. The task before the country is to provide the means by which the best talent may be able to rise, or, as Huxley phrased it, "to catch capacity." The enormous waste of intelligence is the very greatest loss in this country. I am glad that Sir John Cadman and other speakers have insisted on "the open road" for ability in mining, from the bottom to the top. Ability is of no use unless coupled with opportunity. Unfortunately, in the mines ability is sometimes deliberately thwarted. This is a grave charge to make, but, sometimes, through the jealousy of various officials, ability is stifled. But real ability can never be destroyed; it can only be diverted, and in this way the man who would have made a first-class colliery official is perhaps turned into a first-class trade union leader. There is always somebody to recognize ability, and it must find some avenue of use. The natural history of the captains of our industry is of interest. The capable man who got his chance did rise; he or his son became a mining engineer; and the next generation evolved into the coal-owner. This is wholesome progress, and that avenue of progress must be kept open.

Personally, I am glad that the Home Office insist on five years' practical experience in mines. The mining engineer can help the educationist by giving the capable men of humble origin a chance. Efficiency from the mining point of view is a complex matter. The ability to pass examinations is a relatively small item in the make-up of a successful mining engineer, but character—the power of commanding and keeping men in order, and at the same time of gaining their goodwill—does count. So far as the schools are concerned, one feels that the two most important things in mining cannot be taught there. They cannot inform a man's judgment as to costs, the value of labour, or of material. The other matter is judgment as to safety—to know when a place is fit to work in, and, if not fit, how it is to be made fit. These are two things that cannot be taught on the blackboard; they can only be learnt in the mine itself. We must, therefore, never let go the sheet-anchor of experience in training men for what is *the* key industry of this country.

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING.

HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER.
NOVEMBER 12TH, 1918.

MR. A. J. A. ORCHARD, PRESIDENT, IN THE CHAIR.

PRESIDENTIAL ADDRESS.

BY A. J. A. ORCHARD.

In order to give some idea of what effect war conditions have had on the working of a colliery, I have taken for illustration the colliery of which I have charge. The effects of war conditions will vary in most collieries, largely depending on the amount of recruiting that has taken place.

Recruiting.—The St. Helens Collieries at the commencement of the war were employing 1,826 men and boys. At the urgent call for volunteers in 1914, a good response was made, so that by the end of 1914 709 men had enlisted; by the end of 1915 the number had increased to 895; and at the present time the total is 1,276, or 58 per cent. of the pre-war total. Of this number 190 men have been discharged and are again working.

The sudden and indiscriminate withdrawal of so many men necessarily caused serious dislocation in the working arrangements underground. Several districts had to be stopped in order to concentrate the work and economize labour. The only way by which roads could be kept in a reasonable state of repair was by working overtime, and the men loyally responded to every call made upon them.

The most troublesome factor in connexion with recruiting at the colliery was the loss of skilled repairers, such as blacksmiths, mechanics, and electricians, of whom every one of military age and physically fit enlisted. Gradually some of these were replaced by men from other work. When the Miners' Federation insisted on post-war men being combed out of all collieries, these replacements were included in that class, although in most cases they had left a protected occupation in order to work at the colliery. We were again almost denuded of skilled men before the order was modified, and are in that unenviable position at present.

Economic Effects of the War.—For purposes of comparison, I have taken the six months ending June 30th, 1914, as the standard period. The figures given in the tables show the percentage increases and decreases compared with the basis in the standard period. In the cases of cost and selling price the basis is cost per ton and selling price per ton respectively.

UNDERGROUND WAGES COST.

	Percentage increase.
Twelve months ending June 30th, 1915	4
,, ,, ,, ,, 1916	38
,, ,, ,, ,, 1917	49
,, ,, ,, ,, 1918	81
Three ,, ,, September 30th, 1918	114

SURFACE WAGES COST.

	Percentage increase.
Twelve months ending June 30th, 1915	16
,, ,, ,, ,, 1916	37
,, ,, ,, ,, 1917	49
,, ,, ,, ,, 1918	109
Three ,, ,, September 30th, 1918	160

The above costs include the war wage, as I am comparing the economic position without reference to the question of financial responsibility; the higher percentage increase in the surface wages cost is due to the incidence of the war wage on a lower scale of wages.

TOTAL WAGES COST.

	Percentage increase
Twelve months ending June 30th, 1915	6
,, ,, ,, ,, 1916	38
,, ,, ,, ,, 1917	49
,, ,, ,, ,, 1918	85
Three ,, ,, September 30th, 1918	121

The average percentage increase in earnings per shift works out at 88·5, as compared with the 121 per cent. increase in wages cost.

STORES AND MATERIALS.	Percentage increase.	Percentage decrease.
Twelve months ending June 30th, 1915 ...	—	15
,, ,, ,, ,, 1916 ...	65	—
,, ,, ,, ,, 1917 ...	114	—
,, ,, ,, ,, 1918 ...	147	—

The decrease of cost in the first year is owing to the fact that materials drawn from the districts which had been closed were being used up; the rapid rise in the cost of materials was mainly due to the increased price of timber.

General Charges.—These include all charges other than those mentioned.

	Percentage increase.
Twelve months ending June 30th, 1915	31
,, ,, ,, ,, 1916	19
,, ,, ,, ,, 1917	20
,, ,, ,, ,, 1918	49

TOTAL COST, INCLUDING WAGES, MATERIALS, AND GENERAL CHARGES.

	Percentage increase.
Twelve months ending June 30th, 1915	7
,, ,, ,, ,, 1916	41
,, ,, ,, ,, 1917	52
,, ,, ,, ,, 1918	85
Three ,, ,, September 30th, 1918	123

SELLING PRICE.

	Percentage increase.
Twelve months ending June 30th, 1915	12
,, ,, ,, ,, 1916	41
,, ,, ,, ,, 1917	54
,, ,, ,, ,, 1918	70
Three ,, ,, September 30th, 1918	101

The selling price includes the 4s. per ton increase to balance the cost of the war wage.

Output and Number of Persons Employed.—These are shown for the corresponding periods, and are compared with their pre-war bases. After the first year their percentage decrease in each period is very similar, which, considering that a large proportion of the most active men had joined the army, is not unsatisfactory.

TABLE SHOWING PERCENTAGE VARIATIONS IN COST AND OUTPUT.

Particulars.	June 30th, 1914	June 30th, 1915	June 30th, 1916.	June 30th, 1917.	June 30th, 1918.	Sept. 30th, 1918.
	Standard period.	Per cent.	Per cent.	Per cent	Per cent.	Per cent.
Wages: Underground	X	4	38	49	81	114
Wages: Surface ..	X	16	37	49	109	160
Wages: Total	X	6	38	49	85	121
Stores and materials ..	X	−15	65	114	147	—
General charges ..	X	31	19	20	49	—
Total cost	X	7	41	52	85	123
Selling prices	X	12	41	54	70	101
Output	X	−34	−35	−28	−32	−30
Persons employed ..	X	−41	−32	−29	−32	−32

The accompanying diagrams (Plate II.) show the relative variations in a more convenient form. No claim is made that these results are representative of the effects of war conditions on other collieries in Lancashire.

Part IV. of the *Report of the Coal Conservation Committee* gives the recommendations of the sub-committee—twenty in all, and I propose to refer to two of them. Their general substance is to outline the various directions in which the activities of the proposed new Ministry would lie. Assuming that the new authority is created, the most important question is the nature of the machinery through which the Ministry would work. The proposal is that it should take the form of district committees:—

> "For the purpose of obtaining local information and advice, the proposed Ministry of Mines and Minerals should appoint district committees, consisting largely of practical men with mining experience of the district, and including representatives of both mineral lessors and lessees in the district. It would be the duty of these committees to investigate and report on questions referred to them; to prepare draft schemes where necessary, and to give such other assistance to the Ministry of Mines and Minerals, or its Advisory Council, as may be required of them."

Again, on the question of barriers—

> "The proposed Ministry of Mines and Minerals should have plans made shewing the barriers in each colliery district; and for this purpose it should call upon each district committee to obtain the required information, hold local inquiries where necessary, and prepare and submit a plan shewing what barriers in the district must be retained for safety, what barriers could be removed at once, and what barriers could only be moved in certain contingencies. The Ministry would then be in a position to sanction the removal of all unnecessary barriers, and should have statutory authority to do so, notwithstanding covenants in leases."

The main feature of the Report is the proposal to form the new Ministry of Mines and Minerals. The powers proposed to be given to the new authority are wide and even drastic. Hitherto interference in the actual working of mines by the Government has been confined to matters concerning safety or health, excepting, of course, such as there has been owing to the necessities of the war.

The proposal to work through the district committees is a valuable safeguard against unnecessary and incompetent interference. The suggestion as to the advisability of co-operation among the smaller collieries is one deserving serious consideration. Efficiency without doubt lies in the direction of the large unit—perhaps even more so in mining than in other industries—units large enough to justify the employment of highly-trained men in every department. The effective organization and coordination of mining education and research are functions in which the new Ministry can render needed and valuable assistance to the industry.

The last clause in the Report refers to strikes and lock-outs and the importance of setting up machinery of conciliation. So far as labour disputes are concerned, the Lancashire mining industry has a clean war record. In October, 1915, the coalowners and miners of Lancashire and Cheshire came to an agreement, the first clause of which reads as follows:—

> "The coal-owners on their part undertake that no general notice to terminate contracts shall be given at any colliery, and the miners on their part undertake that no general strike or cessation of work shall take place at any colliery in Lancashire and Cheshire during the period of the war, and a further period of six months afterwards."

This agreement has been loyally carried out by both sides.

The spirit of conciliation and forbearance shown by both sides during the war will be equally necessary in the problems that lie ahead—an open and unbiassed mind for each problem as it arises, and an atmosphere created, not by sabre-rattling and mailed fists, but by a spirit of justice and goodwill.

SEPARATION-DOORS AT THE BOTTOM OF THE UPCAST PIT, WORKED AUTOMATICALLY BY TUBS ATTACHED TO ENDLESS-ROPE (UNDER-TUB) HAULAGE.

By CLEMENT FLETCHER.

The main haulage-roads in 1910 and the electric signalling appliances were situated in the main return air-current. This was considered undesirable, and it was decided in 1911 to reverse the air-current and to convert the roads into intake airways. Some form of separation door had, therefore, to be fixed near the bottom of the upcast shaft in order to prevent short-circuiting of the air. Several types of doors and various schemes for operating them were considered, and eventually the doors about to be described were adopted as being the simplest and easiest to work, least likely to get out of order, and most readily adapted to the existing conditions and situation. The smooth working and silent opening and closing of doors with a total air-pressure against them of about 200 pounds is not always easily accomplished.

The pit-shunt consists of a brick arch 17 feet wide and 12 feet high. Four separate roads were required—one empty-tub road for No. 1 West Level, one for the engine-brow, and one full-tub road to serve both these districts. There is in addition a road by which the men travel through the air-doors, but these doors are operated by hand in the usual way. As the space available for the partition between each road was only 5 inches, ordinary brickwork could not be used; and so 5 by 4-inch steel girders, spaced about 7 feet apart and filled in between with reinforced concrete, made a strong and perfectly airtight division wall.

The mechanical arrangements in connexion with the working of the doors are illustrated in Figs. 1 to 4 (Plate III.). There are six automatic doors, two for each road. They are made of ⅛-inch thick sheet-iron, 4 feet 3 inches high by 3 feet 10 inches wide, and stiffened with T-iron. They work vertically in machined gunmetal grooves, and are operated by two Hans-

Renolds roller chains. One end of each chain is attached to the door; it then passes over a countershaft, round the sprocket-wheels on the driving-shaft, and is again attached to the door, thus forming an endless chain. The driving-shaft is placed below the tub rails and is secured to the timber framework. This driving-shaft has (in addition to the sprocket-wheels) a rope-wheel 12 inches in diameter, and is keyed on to the wheel. A flexible galvanized rope ⅜ inch in diameter passes twice round the driving-wheel, then round suitable return wheels, and is attached to a tripper or operating catch. This operating catch is in the form of an L-leg, and is mounted on a small travelling carriage that runs in a channel-iron groove fixed 3 inches clear of the haulage-rope. The action is as follows:—

When the tubs (which are attached to the haulage-rope by clips) arrive at the point *A* (Fig. 1, Plate III.), the axle of the first tub engages with the operating catch and moves it along. This action causes the driving-shaft and sprocket-wheels to revolve, and opens the door. When the door is fully open, the operating catch has travelled to the position *B*. At this point it is automatically released from the tub-axle, the tubs pass on through the doors to the position *C*, where the tub-axle again engages with another catch which reverses the driving-shaft and closes the door on reaching the point *D*. The tubs pass on to a similar arrangement for opening and closing the second door. The rope is practically an endless rope with the two operating catches attached, and is crossed at the point *E*. One set of catches, therefore, when in action reset at the same time as the other set, and *vice versa*.

The chief feature from a mechanical point of view is the simple and efficient way in which the operating catch is disengaged from the tub-axle at the exact moment when the door is fully opened or closed. This is accomplished by cutting out the bottom of the channel-iron groove on which the tripper runs, and by allowing the horizontal end of the L-leg to drop through.

The doors are carefully balanced by weights fastened to the roller chains, and although the speed of the haulage is 2 miles an hour, little or no shock is apparent to the apparatus and gear.

The doors were erected in 1911; no stoppages have occurred since then, and no trouble has been experienced, except through broken or bulged tubs catching the lifting chains, or through a mistake of the lasher-on in spacing the tubs too near together, thereby causing the second train of tubs to begin to open the doors before the first train had completed the closing. When this occurs the small galvanized rope breaks, but it is not necessary to stop and repair it, as the doors can be easily operated by hand by a lad for the remainder of the shift.

The doors were designed by the engineer at the colliery, and I am indebted to him for the details given in this paper.

Mr. **Geo. B. Harrison** (Swinton): I have watched these doors several times, and it is marvellous how quietly they work. There seems to be no jar. The length of the tunnel is just sufficient to allow one door to be closed before the tub strikes the next. At each end of the tunnel is a glass panel through which the haulage lad can look if there is anything wrong. I have seen many doors of various kinds, but I have never seen one where there was so little leakage of air. The roof is just high enough to allow whatever there may be above the tub top to pass. Although there is a big arch, it is all sealed up with cement work except the space required for the tubs to travel along.

Mr. **C. Fletcher** (Atherton) replied to a number of questions as follows: The tubs are always run in pairs. Either one or two, but not more than two, can be taken in. There is barely room for three at once. There is no one to watch the empty tubs going through the doors, but at the top of the haulage-brow where the tubs come out of the doors a boy is stationed to test the clips, sees that they are all safe, and that only two tubs go in. There is no one at the empty end. There are four independent passages or tunnels and one road through each tunnel. There is only 5 inches of space available for each partition, but there is sufficient space for the tubs to pass in addition. The tubs run on ordinary rails, and if a tub can get up the haulage-road, it will go through the doors. No test has been made to ascertain the amount of air lost; but it was so very little that a small hole was cut in the arch over the doors to ventilate the pit-bottom.

DISCUSSION OF DR. GEORGE HICKLING'S PAPER ON "THE MICRO-PETROLOGY OF COAL."*

Dr. **Marie Stopes** (London) wrote: One is in perfect agreement with the author's statement that it is scarcely an exaggeration to say that no rock in the earth's crust is to-day less understood than coal; and it is, moreover, a surprising fact that cannot be too often accentuated. Dr. Hickling attacks the subject as a petrologist, and concerns himself rather with the structure of the mineral itself than with that of the plant-remains which it may contain. He draws attention to the fact that his "most striking results" should not "be thought unduly novel or revolutionary" because they were in a large measure anticipated by Alexander

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* *Trans. Inst. M. E.*, 1917-1918, vol. liii., page 137.

Petzoldt* in 1841, who concluded that coal must have been originally soft and fluid.

Petzholdt was at great pains to demonstrate that when woody matter was either decayed or heated in such a manner as to prevent all the gases which would naturally be given off from escaping, the tissue-structure of the plant-material forming it was then entirely destroyed, and the mass liquefied before forming a coal-like substance. This, and not any suggestion that these alteration-products " were essentially the varieties of coal," is the main interest of Petzholdt's work.

Dr. Hickling appears rather to suggest that Petzholdt succeeded in proving that such artificially-produced products were *really* coals, and says nothing about later work on artificial coals which showed that they differ essentially from true coal. Petzholdt's work is in such out-of-the-way publications that it is useful to draw attention to it, and more exact bibliographic references than Dr. Hickling gives would have been welcome to many people.

Dr. Hickling, following Petzholdt, considers the " streak " left by coals on a rough white surface as ranging from yellow-brown through all shades to black, going in general blacker as the coal becomes richer in carbon. Dr. Hickling affirms this general statement, elaborating it. He states (page 141):

> " Having, in the process of section-cutting, repeatedly observed this close connexion between the carbon-content of the coal and the thinness of section required to produce translucency, it occurred to the writer that there must be a similar relation between the carbon-content and the colour of the streak, since the latter (produced by rubbing a mineral on a rough white porcelain plate) depends on the degree of translucency of the minute particles produced by the rubbing."

By using plates finer ground than those generally provided for mineralogical work, he found the resulting " streak " to be brown for all coal except anthracite, and also that the intensity of the colour is strictly in proportion to the carbon content of the coal, ranging from 65 per cent. of carbon in lignite with a golden " streak " to 93 per cent. of carbon in high-grade coals with a black " streak." He states that the colour is unaffected by any other quality of the coal but the carbon percentage. In order to confirm his view, he obtained from Dr. Wheeler eleven samples of coal having a carbon percentage varying as nearly as possible by intervals of 1 from 80 to 90, and maintains that the regularity of the colour-streak is striking.

In criticism of this conclusion it must be remarked that there is no statement by Dr. Hickling as to the method of analysis followed by Dr. Wheeler; but presumably, as Dr. Wheeler has generally worked with run-of-mine samples on a large scale, these analyses would represent seam analysis and not the analysis of selected bands or portions of the coal. It takes but a cursory examination of a banded bituminous coal to discover that the appearance, analysis, and " streak " of the obviously different portions vary very considerably. If, then, Dr. Hickling's samples, selected on the analysis of their run-of-mine carbon-content, were banded coals, as they can hardly fail to have been, and the " streak " was obtained from a small hand sample, the fact that the " streak " coincided with the carbon content looks like a mere fortunate accident. It is most necessary, therefore, if Dr. Hickling wishes to maintain his position in detail, and to establish differences which go beyond the broad generality of the obvious difference, between lignite, bituminous coal, and anthracite, that he should give much more fully than he has done the method by which his samples are selected and analysed, and the way in which the " streak " is obtained; for it is quite evident that the " streak " from a small corner, whether selected carefully or used by chance, may be very different from the " streak " of a broad surface including various bands in the coal.

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* Who, by the way, was really G. P. A. Petzholdt, who wrote under the name of " Alexander " only, which has led to some difficulties in tracking his papers.—M.S.

A point of such importance and interest to those who handle coal in bulk and are on the look-out for a rough and simple estimate of its composition and character should not be stated with such dogmatic certainty as Dr. Hickling uses without corresponding accurate data accompanying the statement.

Dr. Hickling's next remark, that in his preceding paragraphs " the question of colour has been treated at some length," consequently seems totally inadequate, since practically no details are given at all.

From this (unproved) statement of the external character of coal, Dr. Hickling turns to a consideration of what is seen in microscopic section, and says (page 142):

> " Since . . . an *average* increase in the carbon-content of the particles is accompanied by an *average* increase in colour-density, it must be true of the individual particles that those of high colour-density have a high carbon-content, and *vice versa*."

But his conclusion from this—that portions showing a deeper colour-intensity in section must necessarily have a higher carbon-content—is unsupported by any proof, and appears to be a purely arbitrary pronouncement. As in coal many of the most brightly coloured fractions are known to be, for instance, spore-coats or cuticles which are approximately unchanged in their chemical composition, it amounts to a statement that in cuticular tissue the range of colour varies with the carbon-content, which has no authority. In living tissues the colour of cuticles varies very much, not only with their thickness, but with the species of plant which produces them, some having very characteristic tints, and the rich vivid orange which is one of the brightest tints in the coal-section can be parallelled in the cuticle of living cycads, for instance, as it is matured in the autumn. I have evidence that this vivid orange golden colour of cuticles may be preserved as such apparently unchanged, not only in coal but in mineral petrifaction of fossil plants of equal geological age.

Turning to another aspect of the subject, the banded appearance of coal is described by Dr. Hickling as consisting of alternate layers respectively of "bright," and "dull" or matt coal, the layers being seldom more than ¼ inch in thickness. He offers the opinion that the "dull" coal forms a kind of matrix in which the "bright" bands are scattered in the form of lenticles. He does not refer to the earlier work of Grout (1911) and others, who also held the view that the "dull" coal was the matrix.

Dr. Hickling states that the bright lenticles are "visibly homogeneous," and further on describes them as being in nearly all cases homogeneous, uniformly translucent orange-brown bands. He remarks, however, that the structure of plant-tissue may be sometimes seen, and "occasionally the structure is quite strongly marked," and comes to the conclusion that "apparently homogeneity is simply due to a lack of differentiation between the cell-walls and the enclosed substance, and not to a real disappearance of the vegetable structure itself: and the same reasoning brings conviction that every "bright" band represents vegetable tissue, even though no structure may be anywhere visible in it." He then adopts as a statement, given without proof, the old idea that each separate lenticle of "bright" coal represents a single continuous fragment of plant-tissue.

Most writers have not distinguished between the "bright" bands of coal and the highly "brilliant" bands which occur in much smaller quantity. That Dr. Hickling also fails to realize this difference seems obvious. That he does not mean by his "bright" coal the whole of the coal generally described by other authors as "bright" may be surmised from his statement that these bright lenticles have been described by Jeffrey as "lignitoid," and by Lomax as "jetonized" wood. Dr. Hickling, however, gives no proof whatever that the specimens in which he so clearly shows structure are identical with these exceptionally "bright" bands described by Jeffrey, Thiessen, and others. He states that in the numerous examples which he has examined the majority of tissues are not woody, but soft cortical tissues: his idea, therefore, that to call these bands "lignitoid" wood is to create "a false impression of their nature" lacks logic until he has proved that in a true "jetonized" wood, or what I would prefer to call a "brilliant" band, there is any structure at all. Nevertheless, I agree with him that it is misleading to call such bands "lignitoid," but for quite another reason than his. For some time past I have been studying minutely the "dull" and "bright" banded coal, and I think I have disentangled the confusions and contradictions about them so prevalent in the literature. My observations on the subject are to be presented in a forthcoming paper.

Concerning the "dull" coal, Dr. Hickling notes, as have most previous writers, that spore-coat cuticles and an intervening granular *débris* are to be found therein.

Dr. Hickling mentions further substances in coal, and in particular the bright, pale-coloured bodies generally described as "resin." Like many other writers, he offers no chemical or other decisive tests for this suggestion. He concludes: "There would appear to be no serious reason why at any rate the more definitely homogeneous of these oval bodies should not represent actual fossil resin." He makes a statement without further support that "what would seem to be essentially similar substances ..... form patches of flocculent or 'curdled' appearance ..... still more definitely suggests that they are congealed liquids." The worthlessness of this contribution to the resin question is obvious: definitely-proved facts and not "suggestions" are now needed.

Dr. Hickling then returns to the "mother-of-coal" (*Fusain*: See Stevenson, 1912-1913, and Stopes and Wheeler, 1918), a substance much discussed by previous writers, and says (page 146) that there seems to be—

> "no doubt that the walls of these vessels, as now existing, consist of the altered substance of the original walls, without any addition of other material. This is probably the only instance among the plant-remains to be seen in coal where this simple, direct relationship between the original and the present substance can be said to exist."

Remarks such as these not only do not help matters, but are very confusing. In the first place, all writers, whether those who hold the exploded view of the forest-fire origin of fusain, or those who hold the well-supported view of aërial or sub-aërial decomposition, are agreed that in it the molecules forming the substance of the plant-tissue (principally ligno-celluloses) are more broken down and rather more nearly pure carbon than the rest of the other substances in coal; while, on the other hand, the cuticles and spore-coats—to say nothing of any other cellulose tissue—are so little altered in the coal-substance from what they presumably were when alive that, when isolated, they take on stains like eosin, just as do living cuticles. That "the walls of these vessels" in fusain "are now found to be extremely opaque" depends upon the fact that their molecules have been broken down, just as have the molecules in ordinary charcoal, until they approach near to, although do not entirely coincide with, pure carbon. Dr.

Hickling remarks that Lomax suggested that these masses of fibre represent the result of forest fires. He is apparently unaware that this suggestion was made by Daubrée in 1846, and disproved by Dawson and others, although repeatedly revived since. The alternative suggestion offered by Dr. Hickling differs only in being less exact and less convincing than that offered by Karsten in 1826.

Under the heading of "dull coal," and without any indication that cannels are distinctly different forms of coal from the ordinary "dull" bands in a bituminous coal, such as he has hitherto been considering, Dr. Hickling then speaks of the highly controversial substances which are *not* found in ordinary bituminous coals, but are specifically problems of cannel coal and bogheads, namely, the famous *algæ* of MM. Bertrand and Renault. Nothing is added to previously-published knowledge on this point.

Dr. Hickling considers somewhat carefully the relationship between the plant-tissue visible in coal and the actual coal-substance. Recalling the mineral replacement in such fossils as shells, corals, etc., in which the original substance of the organism has been replaced by other material, he prepares to draw deductions therefrom concerning the nature of the coal-structure. In this connexion he says, instancing particularly the petrified plant-remains, "that only the minutest fraction of the original substance" is still present.

This assumption that in mineral petrifactions of plants the plant is entirely replaced by the mineral molecules is one which has been almost universally made hitherto by palæontologists, but my own experience has recently proved in one or two instances that these apparently entirely mineralized plants have contained unexpectedly large amounts of cell-wall substance which can be separated out by gently dissolving the mineral, the plant material remaining behind in a form so unmineralized as to be capable even of distinctive staining, like fresh material. It is, therefore, not such an axiom as Dr. Hickling assumes that the plant-remains in coal must necessarily be replaced and not composed of their original substance.

Dr. Hickling then postulates a liquid substance which "diffused" through the walls of the tissue until the plant-fragments became saturated with this liquid decomposition product of other vegetation. He states definitely (page 149) that—

> "The cell walls themselves have doubtless been impregnated with, if not ultimately replaced by, the same material; and since in the large majority of fragments of 'lignitoid' no distinction between 'cell walls' and 'contents' is now visible, it would seem probable that considerable replacement of the walls has usually taken place."

It is difficult to discuss this point of view in detail without presenting fully my own, which differs in many respects from it. Essentially the difference may be summed up in a few words as follows:—If, as a result of my observations seems probable, the true "lignitoid" bands in the coal correspond more or less exactly with the "brilliant" conchoidal zones, and if, on the other hand, the tissue-containing portions are on the whole the ordinary "bright" zones of the coal, Dr. Hickling is really arguing from two different portions of the coal, thereby building up his apparently logical argument from data obtained about different substances.

As a result of my own observations, it appears that Dr. Hickling's treatment of "lignitoid" and "bright" bands as equivalent, and the remaining constituents of coal as forming the "dull" bands, appears ultimately to be confusing.

Apart from his "bright," Dr. Hickling describes four "remaining constituents" which together form the "dull" bands. These he describes as follows:—

(1) The matrix, or ground-mass. This he states to consist of very minute fragments of "lignitoid" character. Consequently, from a chemical point of view, this constituent No. 1 cannot differ essentially from his "bright" substances.

(2) He groups together cuticles, spore-coats, and algæ. These apparently are grouped together because they are all "much paler in colour than any other of the 'organic' constituents of coal." Dr. Hickling allows that in these bodies it is probable that a considerable part of the original substance remains.

(3) The oval or flocculent bodies described as "resin." Dr. Hickling also makes the statement about No. 3 that "there can be no doubt that these masses were originally liquid." In his paragraph on No. 3 he has but these two sentences, and these sentences are directly contradictory. If the bodies *were* resin, then there can be no doubt that these masses were originally *not* liquid when considered from the point of view of coal. Resin as exuded from the tree in lumps, or as filling the resin canals in the plant-structure, is essentially insoluble in water, and it would come as such insoluble masses into the vegetable mulch which was forming the coal. It is true that far back in its history, while the plant was still living, it passed like all soft organic substances through a liquid stage, but I suppose it would be difficult to find any substance in the plant body less "originally liquid" when introduced into the coal-substance or when undergoing the partial decomposition which was one of the phases of coal-production.

(4) Dr. Hickling's four groups are of quite different equivalent value, and his fourth consists of "fragments of mother-of-coal." This he apparently includes in the part constituting the "dull" bands, although these portions of the coal are not in any

sense essentially part of the true "dull" hard coal, but are a particular type of substance in themselves.

Summing up Dr. Hickling's position, then, he divides coal (*a*) into these "bright" or lignitoid bands, and (*b*) into the "dull," subdividing the "dull" into four artificially separated substances forming various portions of the coal of quite different equivalent value and by no means all characteristic of true "dull" coal. The algæ, for instance, in his No. 2 are found only in canneloid coal, while the mother-of-coal composing his No. 4 is not only not at all characteristic of ordinary hard "dull" coal, but is much more frequently found as lenticles interspersed with "bright"; and it is further never found in pure cannels.

In his four groups of bodies supposed to form the "dull," he elects to place the resinous bodies as one group, but ignores all the other substances which can be seen or guessed to be in coal, as well as such chemical crystals as iron sulphide, which is doubtless the ultimate reduction product of organic matter in many instances. He says nothing of the numerous other substances which without too great or complete decomposition the plant must have contributed to coal.

When Dr. Hickling comes to speak in his conclusion of his "impregnating" material which is supposed to have diffused through the original cell-wall tissue, he goes entirely into the realm of theory by stating that he would anticipate that the particular plant-membranes must have exerted "important selective action in determining what substances should pass through it." With our present knowledge of coal, such a suggestion is fantastic.

Dr. Hickling, again reverting to resins, says "it is sufficient merely to mention" that Huxley, in 1870, referred to the important part played by spores in imparting a resinous quality to coal, continuing that "there is no reason to doubt that the spore-coats of the carboniferous plants may have been more or less resinous." This perpetually repeated statement, that the spore-coats are resinous, appears in one paper after another, without any critical examination or any attempt to offer proof of the original statement, or of any deductions drawn from it. Contrary to Dr. Hickling's assumption, there appears to be not a little evidence that the spore-coats are entirely devoid of resin. With his general warning, however, one can be in agreement, for, as he points out, it is not desirable to assume, as has often been done in the past, that the greater part of the transparent substances of amber-like appearance are really resinous in their nature.

Dr. Hickling's final separation of coal into (1) humic, (2) canneloid, and (3) bogheads, does not follow logically from the body of his paper; but as it is based on Potonié's already well-known work, it need not be discussed.

The valuable feature of the paper is its coloured Plate I., showing exceedingly well the woody tissue in a coal-section.

Dr. GEORGE HICKLING (The University, Manchester) wrote: In reply to Dr. Stopes' valuable contribution to this discussion, I would first gratefully acknowledge her testimony that the paper is "provocative." Its main intention has thus been fulfilled; and no one, I am sure, will admit more readily than Dr. Stopes that it is more than time that some workers were provoked into the investigation of coal.

With the majority of Dr. Stopes' remarks I am in the fullest agreement—more so than she appears to realize. Comparatively few call for further explanation on my part, and very few indeed I would wish to dispute. Such comments as seem to be required I will make seriatim.

With regard to Petzholdt's experiments, I agree that my compressed remarks might be taken to suggest that *real* coal was artificially produced, although it should be fairly evident that such could not be the case. What is true, of course, is that the products have many of the physical properties of the various types of coal, including the colours.

Dr. Stopes very properly emphasizes the extreme importance of a thorough investigation of the relation which I stated to exist between colour and chemical composition; and I would repeat that its importance lies not merely in its possible commercial application as a ready means of obtaining an approximate measure of carbon-content, but still more as a means of linking up chemical and microscopic observations. That a much fuller and more precise investigation than I have been able to give must be undertaken I am fully conscious of, and for that very reason stated the relationship in the most definite form, in the assurance that it would then be challenged. At the same time, the evidence is perhaps stronger than Dr. Stopes may think. The prominence given in the discussion to the evidence of the samples obtained from Dr. Wheeler's laboratory may tend to obscure the issue. My aim in securing those samples was not so much to see whether very small differences of carbon-content could be detected by colour, but rather to see whether, within such a small range, any exceptional colour would be found. If it had not been necessary to pick the material somewhat hurriedly, a further set of specimens presumed to have identical carbon-contents would have served my main object still better. The objection on the ground that the specimens were run-of-mine samples (as doubtless they were) has therefore less weight, in that an uncertainty of 2 or 3 per cent. is immaterial to my argument; and although "visibly different" portions of a seam may depart greatly from the main mass in composition, there is a very strong presumption that samples which do not differ visibly from the normal also differ little in composition, notwithstanding the fact that each specimen is a complex aggregate of widely-differing constituents.

My main argument, however, was based, not on any attempt to trace relations between small differences of composition and colour, since it was obvious that only the most elaborate investigation on those lines could suffice, but on the much more general evidence that *all* low-carbon coals are relatively pale-coloured and *all* high-carbon coals dark. Of this there is a very large body. To put the matter more precisely, in low-carbon coals the proportion of light-coloured constituents is high, while in high-carbon coals the proportion of dark-coloured constituents is high. It follows of strict logical necessity that the average carbon-content of light-coloured particles is correspondingly lower than that of dark particles. If the component substances were unrelated, the deduction must stop at that point. Since, however, the components are for the most part intimately-related substances, the presumption is strong that what is true of the average is true of the great majority. Dr. Stopes has clearly failed to realize this argument when she refers to my contention that the individual particles with high colour-density have a high carbon-content, and *vice versa*, as " unsupported by any fraction of proof." The contention is, in fact, valid exactly in proportion as the correlation between the average colour of the mass and its average carbon-content is precise.

It does not appear to me that Dr. Stopes' reference to the colour of the cuticles of living plants has any real bearing on the question. Only in exceptional cases have they or any other cell-walls of living plants any perceptible colour at all in thin section, whereas we are now concerned with a coloration which is nearly if not quite universal to all the organic products which constitute coal, and of such intensity that considerable skill is required in order to prepare a section sufficiently thin to be other than quite opaque.

With regard to the question of " bright " coal, I would only say at this point that the bands with well-defined structure, such as that of which a minute portion is shown in Plate I., are unquestionably " bright." Further, the brilliancy of any portion of the coal must be proportional to its homogeneity. Hence it is to be anticipated that the most brilliant bands will show little or no differentiation of structure under the microscope. Such lack of differentiation is certainly exhibited by many portions of coal which are unquestionably altered vegetable tissues.

Dr. Stopes is under a misapprehension in supposing, as apparently she does, that I have stated that resins may be seen in coal. In view of the innumerable statements of other people to that effect, I have hunted long for objects which might without obvious violence to the microscopic evidence be regarded as such —but that is a very different matter. What is in effect stated is that certain objects appear, on the evidence of their visible form and structure, to be "congealed liquids," and not plant-fragments in the ordinary sense. Nothing whatever is stated as to their chemical nature. I am very glad to have Dr. Stopes' support to my opposition to the futile efforts which have repeatedly been made to prove the existence of resins by means of the microscope.

That the substance of "mother-of-coal" has undergone a greater chemical change than most other constituents of the coal is probably true, but the fact is in no way inconsistent with the statement that the resulting substance in that case is derived directly from the original substance without the addition of other organic materials—a statement which appears to be true in few, if any, other cases. Suggestions that "fossil charcoal" was due to the actual burning of wood are a good deal older than Daubrée: the revival of the idea by Lomax was merely referred to as being familiar to the audience.

Perhaps I ought to accuse Dr. Stopes of misconstruction in saying that I describe Bertrand's and Renault's "algæ" as occurring in "dull coal." If she will look at the paragraphs again, she will see that the statement is hardly justified. In any case, we are perfectly agreed as to the facts—the "algæ" are *not* normal constituents of ordinary coal, as specifically stated at the beginning of the paragraph in question.

It is much to be desired that Dr. Stopes should publish in more detail than she has yet done the precise evidence regarding the preservation, in an unaltered condition, of plant-tissues. Staining methods provide an invaluable means of discrimination among a limited range of known substances which compose living plants, but such evidence must be accepted with caution when the range of possible chemical constitution is indefinitely extended. However, the view expressed in my paper—that coal is in the main a deposit of vegetable structures infilled with, and more or less replaced by, liquefied organic products—is quite independent of the question whether or no a certain amount of the original substance of the cell-walls remains, as I think the paper itself makes clear. Dr. Stopes admits that the main argument is "apparently logical," and only appears to fear that I may have been mistaken in my belief that portions of the coal-substance showing vegetable structure are actually continuous with portions which are really homogeneous (so far as the microscope can detect). I can only assure her that the facts are quite accurately stated in the paper.

Dr. Stopes' varied remarks concerning the "remaining constituents" which form the "dull bands" are largely based on a natural confusion of ideas. Coal in general is either "bright" or not bright—that is, "dull." The little I have said with regard to cannels—which are surely well-known to everyone to differ in many essentials from "bituminous" coals—has therefore been included under the heading of "dull" coal in the most general sense of that term. In a more special sense, the ordinary bituminous coals are divisible into "bright" and "dull" layers. If the aim of the paper had been to give an elaborate description of the different types of coal, naturally the constituents of cannels would have been separated entirely from those of "common" coals. Since, however, the aim is merely to indicate the nature of the leading visibly distinct constituents of coal in general, they naturally come together. No misconception could, I think, arise in the mind of anyone reading the paper *as a whole.*

The discussion of "the oval or flocculent bodies described [by others, but not by me] as "resin" is scarcely helpful, since it again attributes to me a definite statement which I have never made, and exposes a supposed contradiction which does not exist. *If* the objects in question be fossil resin, then they unquestionably *were* originally liquid, in the sense that any structures or lack of structures which they now show are the outcome of the fact that they were liquid secretions (however solid *after* secretion) and not organized vegetable tissues—the only sense in which original liquidity is here in question.

With regard to the suggested "selective action" of plant-membranes, I would only ask whether Dr. Stopes has yet heard of a semi-permeable membrane which did *not* exert such action?

The last reference to the resin question in Dr. Stopes' remarks has my fullest sympathy. The whole paragraph from which she quotes was intended to re-emphasize—I thought, quite clearly—that in my opinion the rôle played by resins is entirely non-proven so far as microscopic evidence goes. It is still true that the spore-coats of carboniferous plants *may* have been more or less resinous, although no substantial support for the supposition has yet been offered. Here I would again repeat the substance of a previous reply. When the non-chemical writer speaks of resin, he presumably refers to the familiar plant-secretion so named. The chemist, on the contrary, includes as "resins" a large and vague class of substances of which I have so far been unable to find an intelligible and precise definition. Herein doubtless lies the secret of the apparent discrepancy between the evidence of the microscope and the conclusions of some chemists, for whom "resinic derivatives" play a very large part in the build-up of coal.

Dr. **MARIE STOPES** subsequently wrote: When Dr. Hickling suggests that he " ought to accuse Dr. Stopes of misconstruction in saying that I describe Bertrand's and Renault's 'algæ ' as occurring in ' dull coal,' " he must be judged by his words as published, and not by what he possibly intended to say. On page 149 his exact words are: " the remaining constituents of coal (forming the 'dull bands') may be grouped under the following four headings. . . . . (1) The ' matrix ' or ' groundmass ' of the dull bands. . . . . (2) Cuticles of stems or leaves, spore-coats, and the ' algæ ' of Bertrand and Renault."

Dr. GEORGE HICKLING, in reply, wrote: The paragraph quoted by Dr. Stopes contains later (page 150) the words. . . . . "the ' algæ ' . . . . . are rare in ordinary coals." It is also preceded by the statement (page 146) that these bodies . . . . . "are restricted in their occurrence to cannel coals and Bogheads." The difference really arises from the fact that Dr. Stopes would attach a rather more precise and restricted meaning to the term "dull coal" than I have intended to do.

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER, DECEMBER 17TH, 1918.

MR. A. J. A. ORCHARD, PRESIDENT, IN THE CHAIR.

DISCUSSION OF PROF. F. W. HARDWICK'S PAPER ON "THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION."*

MR. WILLIAM PICKUP (Blackburn): The paper under discussion will prove valuable in two ways: it will not only be helpful to the Engineering Training Organization and provide it with the information it requires, but it will direct increased attention to one of the most important subjects affecting the mining industry at the present time, that is, the better training and higher education of workmen, officials, and those who are to control the industry in future. Employers in the future will do well to realize more than they have in the past the advantage of and insist upon a higher standard of education amongst their officials. Aspiring students should be encouraged and assisted to pass from the local classes to the district Colleges and from there to the University; and a complete co-ordination of the whole system of mining education from bottom to top should be attained.

The importance of technical education in mining in the past has not been sufficiently realized, with the result that the industry as compared with others has suffered. The industry of the future will be of much greater complexity and difficulty than in the past, and a higher technical education for those controlling it will be required.

The industry in the past has too often been carried on at a low standard of efficiency, and it should give proof of its belief in the value of highly-trained men by adequate moral and financial support, and by encouraging students in sufficient numbers. The problem is to produce a number of persons for each of the different grades of employment sufficient to meet not only the demand but the needs of the industry.

* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 94.

Workmen.—The workman will obtain his principal education at a public elementary school. On reaching the highest standard and commencing work at 14 years of age, he should continue his attendance at continuation classes under the new Education Act until 16, and later 18, for which the necessary facilities should be provided, taking in those two years the preliminary technical courses as arranged by the local education authorities.

Officials.—In considering the training of the official classes, one needs at once to distinguish between the future official who is rising from the practical side and the one who is coming direct from school. In other branches of engineering, institutions are free to make such regulations as to education as they deem best, but in coal-mining regard has always to be had to the provisions of the Coal Mines Acts respecting firemen, under-managers, managers, and surveyors—not only with regard to the subjects for examination, and the standard to be attained, but also with regard to the period and kind of practical work which is an essential qualification for candidates for these certificates.

Firemen.—The workman desirous of becoming a fireman will begin to specialize, and while attending his daily work will take at the local mining classes the first and second year's mining courses, passing the Home Office examination for the Fireman's Certificate at 25 years of age.

Under-managers.—Promising practical mining students desirous of going forward and becoming under-managers will, while still attending their daily work, take at the local mining classes the third and fourth year's mining courses as provided by the local education authorities, passing the Home Office examination for the Second Class Certificate of Competency as an under-manager at 23 years of age.

Managers.—Practical students desirous of going forward and becoming managers will, while still attending their daily work, take, either at the local mining classes (where facilities are available) or at the district Mining Colleges, the fifth year's mining course, passing the Home Office examination for the First Class Certificate of Competency as a colliery manager at 23 years of age.

The county and local authorities should encourage their most promising students to go forward from the local classes to higher studies at the district Colleges and pay fares and fees in these cases. The scholarships offered by the local education authorities and other bodies should also be increased, both in number and value, until it will no longer be possible for a boy to be prevented by financial reasons from receiving a University training. It should be made clear to all that there is no position to which a capable student may not aspire.

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The industry in the past has too often been carried on at a low standard of efficiency, and it should give proof of its belief in the value of highly-trained men by adequate moral and financial support, and by encouraging students in sufficient numbers. The problem is to produce a number of persons for each of the different grades of employment sufficient to meet not only the demand but the needs of the industry.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 94.

Colliery Mechanical and Electrical Engineers.—The training of these classes of officials is outside the present discussion; they will be prepared by taking the usual theoretical and practical courses necessary to properly qualify them for their future work.

Students.—We may now consider the student coming into mining direct from a public school. Youths who have this advantage will be well advised to matriculate before leaving, in order to qualify themselves for entrance to the University.

Surveyors.—The student intending to become a surveyor may enter upon his career direct from school through a regular pupilage with a mining engineer, or at a colliery, or by taking the day courses in surveying at a Mining College, passing the Home Office examination for the Surveyors' Certificate as soon as he is qualified and able to do so; or he may take it at the same time as his examination for the First Class Certificate of Competency.

General Managers, Agents, and Mining Engineers.—It is to the University or to the Technical College of University rank that we must look for the adequate training of future managers of the largest concerns, agents, mining engineers, and Inspectors of Mines. The manager of a large colliery has great responsibilities. He must be able to initiate, consider, and decide upon proposals for working both seams that hitherto have been neglected as unprofitable and seams at greater depth, for generating power and distributing it electrically to distant points, or for the installation of plant for the distillation of coal and the recovery of bye-products, etc.; in fact, the successful development of the coal-mining industry demands not only the expert in various branches of engineering or of chemistry, but also the manager with a large outlook, a wide knowledge, and a far-reaching policy. The control of an industry of this importance not only justifies but demands an adequate training, since any failure to make the best use of our mineral deposits can never afterwards be remedied, and also because an improvement in mining methods may give so large a proportionate return.

A pupil of this class should remain at a public school until 18 years of age, and leave after passing the matriculation or equivalent examination. He should then spend twelve months working underground in a mine, when he should enter a University or a Technical College of University rank in order to take the full-time degree course.

There is little doubt in all applied studies that the sooner a pupil gets into contact with the industry he intends to enter the better. By doing so he is more capable of taking an intelligent interest in the instruction given. If he is the right kind of boy, the practical experience he obtains will make him take up the theoretical part of his training with greater zest; while if he is not the right kind of boy, he will probably find the work distasteful and seek a more congenial occupation.

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Mr. S. C. Laws (Wigan): My experience of mining education suggests that full-time courses of technical training should be much more extensively followed by those who are destined to occupy the most responsible positions. At the present time the industry very largely accepts the minimum required by the Coal Mines Act in the form of the First Class Certificate of Competency as evidence of adequate preparation for practically all forms of employment. As in other industries, positions of responsibility in which momentous and often immediate decisions have to be made from day to day and hour to hour can only be adequately filled by men who are able to combine an ample technical knowledge with a brisk mentality and wide outlook, a combination to the development of which years of study under suitable conditions may usefully be spent. Probably if the full-time courses in mining provided by Universities or Technical Colleges were more definitely associated with the industry in the way that is being begun in South Wales, for example, these would more readily command attention and confidence. Thus a boy who leaves the secondary school at 17 years of age and becomes a mining apprentice could spend a year at the colliery, attending part-time classes meanwhile, before entering upon the first year of his full-time mining course. If this latter were to occupy four sessions each of six months' duration, the apprentice would be able to complete this and obtain nearly four years' practical experience before completing his apprenticeship and securing his Home Office Certificate at 23. With this system in operation, the full-time mining course would fall into its proper place as an essential part of apprenticeship. And just as a progressive and suitably organized course of study is essential to progress on the technical side, so at the mine the apprentice should be enabled by a due allocation of his time throughout apprenticeship to gain a well-balanced experience of all aspects of mining work. Moreover, in view of the necessity in the national interest that the mining industry should secure the fullest possible use of the best brains in whatever station of the social order these are to be found, it is essential that there should be a more adequate supply of scholarships to the full-time mining course. Holders of such scholarships should receive a practical training similar to that suggested for apprentices.

For the minor official positions part-time courses of technical training should continue to apply. By the Education Act of 1918, however, these will undergo an enormous and fundamental development. A few years after the adoption of this Act all mine employees, in common with other young persons, will be required to attend schools for 320 hours in each year until 18 years of age. Moreover, this attendance is to be made during ordinary working hours, and not, as has been usual hitherto, at the end of the day. With the system of part-time day schools in operation, it would appear an obvious step for the industry to provide for a continuation beyond the age of 18 years of day classes—say, on one day per week—in the way of specially-selected young persons: in this way would be created a trained supply of workers from which to recruit the minor official positions.

Dr. George Hickling (Manchester): My remarks must be regarded merely as those of an onlooker and not of an expert. One point on which I think everyone is agreed is the fact that the training of the colliery manager must be of the widest possible character; and such remarks as I make will be directed towards indicating slightly the part which, in my opinion, the Universities might play in providing for such an education. The valuable communication sent by Sir John Cadman* seems to indicate the principal difficulty which has caused some confusion in the discussion of this problem, namely, that while it is clearly desirable that facilities should be provided by which a man may pass from the lowest to the highest positions in the colliery, it must nevertheless be recognized that the training required for different types of mine workers is essentially different in character. For the practical purposes of educational organization three fairly well-marked grades may be recognized: first, that of the miners up to the grade of firemen; secondly, under-managers and pit managers; thirdly, the general managers and agents. With regard to the first two, the training which is absolutely essential to their work appears to me to be primarily technical in character, and is probably to be most effectively provided in the various technical classes and institutions which exist for that purpose. On the other hand, the third group requires an altogether wider training. While the general manager must naturally possess the technical knowledge required by other officials, and indicated by the requirements for the mine-manager's certificate, the problems which mainly claim his attention are becoming ever wider in scope. The day when it was sufficient for the colliery manager to choose from the seams under his control those which could be worked at the greatest profit and to work those on traditional lines, merely disposing of the output at the highest price which he could obtain, is rapidiy passing. The actual process of mining is becoming more and more a highly specialized branch of mechanical engineering. The increasing application, for example, of electrical power in mining operations is making it evermore necessary that the colliery manager shall be competent to enter into an informed discussion as to the relative merits of different designs of electrical machinery. Therefore, while it cannot be possible that among his many other attainments the colliery manager shall be an expert electrical engineer, it is clearly desirable that a part of his training shall have been acquired in some institution where he could come into contact with those whose business it is to design electrical machinery and more especially to study the fundamental principles underlying such design. To refer, again, to another question, the proper utilization of coals is rapidly rising in importance. It is no longer sufficient to consider coal merely as a fuel: it has now to be regarded still more as a source of the most valuable bye-products. Seams which were formerly neglected must now be regarded as national assets of the highest value, and it becomes the duty of the directing manager of the colliery to see that all the seams in his royalty are utilized in the most effective manner. The study of the coals themselves must be primarily the work of the coal chemist; and, again, it is obvious that the colliery manager cannot be expected to possess the detailed knowledge of the highly specialized branch of organic chemistry which is essential to this study; but it is also clear that he should be in a position fully to appreciate and intelligently to discuss the work which the chemist does on his behalf. For this purpose again it is clearly to be desired that the manager shall receive some of his training in an institution where such work is in progress and where he may learn something of its methods and underlying principles, although he himself cannot spare the time necessary to acquire the mass of detailed information essential to the actual conduct of chemical investigation.

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* See *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 163.

The two points which have been mentioned may suffice to indicate to some extent the way in which a training in an institution of University character should be of the highest value to the general manager of a colliery. Many other illustrations of similar type will doubtless occur to the members present. In conclusion, while the advantages of such a training are clearly desirable for the man who from the outset is definitely destined to become a general manager, it is also to be remembered that the same advantages should be open to any colliery official whose capabilities and ambitions may lead to the hope that he will some day be able to rise to that position.

Mr. JOHN GERRARD (Worsley): Speaking generally, if there is an awakening to the greater value of scientific mining, then, surely the mining industry must not be behind. We must devote attention to the needs of those who work in the mines, of those who will become mining officials, and of those who will be managers and mining engineers. To the last class should be available the highest University or College education. Employers will have to show a wider appreciation of the value of University rank.

Mr. ARTHUR MILLER (Pendlebury): With regard to the question of heredity in the mining profession, I think that when a mining man gets to 50 or 60 years of age you will not find him putting his son to mining unless it is an exceptional case, and he is in an exceptional position for giving him a good professional training. With respect to the suggested division between managers, agents, and mining engineers, when I look round I fail to see that there is any real division between the managers and the agents. Nearly all the latter have been managers, and I do not think that they obtained any further scientific training except what they got in connexion with their work; but I should judge that they have studied psychology to some extent and understand human nature. They are able to turn that knowledge to some use. But how can we start with three divisions? How are we to know at the start who will prove to be the best man?

We are altogether behind in the standard of knowledge that is required. Take the case of the firemen's examination. What is it? Something that a schoolboy could pass, nothing more nor less. We must, of course, have these certificated men, but I say deliberately that every youth who proposes to become a fireman should be able to pass an examination equivalent to a matriculation examination. He would do it if he could see before him sufficient encouragement, something which would make it worth his while to pass it. If this country is to fight successfully its competitors abroad, adequate remuneration must be given for scientific knowledge and training.

The President (Mr. A. J. A. Orchard): The subject has been fairly discussed and there is general agreement that increased facilities for training mining students are required. The particular order of training is not at the present stage in Lancashire so urgent a problem as the question of organizing and co-ordinating existing schools, which require linking up with the industry on the one hand, to ensure the supply of students, and with the University on the other, so that the industry may ultimately benefit from the highest class of teaching.

Mr. David E. Thomas (St. Helens) wrote: One outstanding feature in the education of the mining student is the almost general absence of co-operation and co-ordination of efforts between education authorities and the mining industry. The interdependency of the theoretical and practical training must receive fuller consideration. It must be more fully recognized that any scheme for the training of mine officials must be of a dual character: the practical side of the training must be co-ordinated with the theoretical.

In the past our evening Technical Schools, full-time Mining Colleges, and Universities have struggled along on their own initiative, and, with the exception of one or two cases, confined themselves entirely to the theoretical training of mine officials.

different" portions of a seam may depart greatly from the main mass in composition, there is a very strong presumption that samples which do not differ visibly from the normal also differ little in composition, notwithstanding the fact that each specimen is a complex aggregate of widely-differing constituents.

My main argument, however, was based, not on any attempt to trace relations between small differences of composition and colour, since it was obvious that only the most elaborate investigation on those lines could suffice, but on the much more general evidence that *all* low-carbon coals are relatively pale-coloured and *all* high-carbon coals dark. Of this there is a very large body. To put the matter more precisely, in low-carbon coals the proportion of light-coloured constituents is high, while in high-carbon coals the proportion of dark-coloured constituents is high. It follows of strict logical necessity that the average carbon-content of light-coloured particles is correspondingly lower than that of dark particles. If the component substances were unrelated, the deduction must stop at that point. Since, however, the components are for the most part intimately-related substances, the presumption is strong that what is true of the average is true of the great majority. Dr. Stopes has clearly failed to realize this argument when she refers to my contention that the individual particles with high colour-density have a high carbon-content, and *vice versa*, as "unsupported by any fraction of proof." The contention is, in fact, valid exactly in proportion as the correlation between the average colour of the mass and its average carbon-content is precise.

It does not appear to me that Dr. Stopes' reference to the colour of the cuticles of living plants has any real bearing on the question. Only in exceptional cases have they or any other cell-walls of living plants any perceptible colour at all in thin section, whereas we are now concerned with a coloration which is nearly if not quite universal to all the organic products which constitute coal, and of such intensity that considerable skill is required in order to prepare a section sufficiently thin to be other than quite opaque.

With regard to the question of "bright" coal, I would only say at this point that the bands with well-defined structure, such as that of which a minute portion is shown in Plate I., are unquestionably "bright." Further, the brilliancy of any portion of the coal must be proportional to its homogeneity. Hence it is to be anticipated that the most brilliant bands will show little or no differentiation of structure under the microscope. Such lack of differentiation is certainly exhibited by many portions of coal which are unquestionably altered vegetable tissues.

Dr. Stopes is under a misapprehension in supposing, as apparently she does, that I have stated that resins may be seen in coal. In view of the innumerable statements of other people to that effect, I have hunted long for objects which might without obvious violence to the microscopic evidence be regarded as such —but that is a very different matter. What is in effect stated is that certain objects appear, on the evidence of their visible form and structure, to be "congealed liquids," and not plant-fragments in the ordinary sense. Nothing whatever is stated as to their chemical nature. I am very glad to have Dr. Stopes' support to my opposition to the futile efforts which have repeatedly been made to prove the existence of resins by means of the microscope.

That the substance of "mother-of-coal" has undergone a greater chemical change than most other constituents of the coal is probably true, but the fact is in no way inconsistent with the statement that the resulting substance in that case is derived directly from the original substance without the addition of other organic materials—a statement which appears to be true in few, if any, other cases. Suggestions that "fossil charcoal" was due to the actual burning of wood are a good deal older than Daubrée: the revival of the idea by Lomax was merely referred to as being familiar to the audience.

Perhaps I ought to accuse Dr. Stopes of misconstruction in saying that I describe Bertrand's and Renault's "algæ" as occurring in "dull coal." If she will look at the paragraphs again, she will see that the statement is hardly justified. In any case, we are perfectly agreed as to the facts—the "algæ" are *not* normal constituents of ordinary coal, as specifically stated at the beginning of the paragraph in question.

It is much to be desired that Dr. Stopes should publish in more detail than she has yet done the precise evidence regarding the preservation, in an unaltered condition, of plant-tissues. Staining methods provide an invaluable means of discrimination among a limited range of known substances which compose living plants, but such evidence must be accepted with caution when the range of possible chemical constitution is indefinitely extended. However, the view expressed in my paper—that coal is in the main a deposit of vegetable structures infilled with, and more or less replaced by, liquefied organic products—is quite independent of the question whether or no a certain amount of the original substance of the cell-walls remains, as I think the paper itself makes clear. Dr. Stopes admits that the main argument is "apparently logical," and only appears to fear that I may have been mistaken in my belief that portions of the coal-substance showing vegetable structure are actually continuous with portions which are really homogeneous (so far as the microscope can detect). I can only assure her that the facts are quite accurately stated in the paper.

Dr. Stopes' varied remarks concerning the "remaining constituents" which form the "dull bands" are largely based on a natural confusion of ideas. Coal in general is either "bright" or not bright—that is, "dull." The little I have said with regard to cannels—which are surely well-known to everyone to differ in many essentials from "bituminous" coals—has therefore been included under the heading of "dull" coal in the most general sense of that term. In a more special sense, the ordinary bituminous coals are divisible into "bright" and "dull" layers. If the aim of the paper had been to give an elaborate description of the different types of coal, naturally the constituents of cannels would have been separated entirely from those of "common" coals. Since, however, the aim is merely to indicate the nature of the leading visibly distinct constituents of coal in general, they naturally come together. No misconception could, I think, arise in the mind of anyone reading the paper *as a whole.*

The discussion of "the oval or flocculent bodies described [by others, but not by me] as "resin" is scarcely helpful, since it again attributes to me a definite statement which I have never made, and exposes a supposed contradiction which does not exist. *If* the objects in question be fossil resin, then they unquestionably *were* originally liquid, in the sense that any structures or lack of structures which they now show are the outcome of the fact that they were liquid secretions (however solid *after* secretion) and not organized vegetable tissues—the only sense in which original liquidity is here in question.

With regard to the suggested "selective action" of plant-membranes, I would only ask whether Dr. Stopes has yet heard of a semi-permeable membrane which did *not* exert such action?

The last reference to the resin question in Dr. Stopes' remarks has my fullest sympathy. The whole paragraph from which she quotes was intended to re-emphasize—I thought, quite clearly—that in my opinion the rôle played by resins is entirely non-proven so far as microscopic evidence goes. It is still true that the spore-coats of carboniferous plants *may* have been more or less resinous, although no substantial support for the supposition has yet been offered. Here I would again repeat the substance of a previous reply. When the non-chemical writer speaks of resin, he presumably refers to the familiar plant-secretion so named. The chemist, on the contrary, includes as "resins" a large and vague class of substances of which I have so far been unable to find an intelligible and precise definition. Herein doubtless lies the secret of the apparent discrepancy between the evidence of the microscope and the conclusions of some chemists, for whom "resinic derivatives" play a very large part in the build-up of coal.

Dr. **Marie Stopes** subsequently wrote: When Dr. Hickling suggests that he "ought to accuse Dr. Stopes of misconstruction in saying that I describe Bertrand's and Renault's 'algæ' as occurring in 'dull coal,'" he must be judged by his words as published, and not by what he possibly intended to say. On page 149 his exact words are: "the remaining constituents of coal (forming the 'dull bands') may be grouped under the following four headings. . . . . (1) The 'matrix' or 'groundmass' of the dull bands. . . . . (2) Cuticles of stems or leaves, spore-coats, and the 'algæ' of Bertrand and Renault."

Dr. **George Hickling**, in reply, wrote: The paragraph quoted by Dr. Stopes contains later (page 150) the words. . . . . "the 'algæ' . . . . . are rare in ordinary coals." It is also preceded by the statement (page 146) that these bodies . . . . . "are restricted in their occurrence to cannel coals and Bogheads." The difference really arises from the fact that Dr. Stopes would attach a rather more precise and restricted meaning to the term "dull coal" than I have intended to do.

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER, DECEMBER 17TH, 1918.

MR. A. J. A. ORCHARD, PRESIDENT, IN THE CHAIR.

DISCUSSION OF PROF. F. W. HARDWICK'S PAPER ON "THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION."*

MR. WILLIAM PICKUP (Blackburn): The paper under discussion will prove valuable in two ways: it will not only be helpful to the Engineering Training Organization and provide it with the information it requires, but it will direct increased attention to one of the most important subjects affecting the mining industry at the present time, that is, the better training and higher education of workmen, officials, and those who are to control the industry in future. Employers in the future will do well to realize more than they have in the past the advantage of and insist upon a higher standard of education amongst their officials. Aspiring students should be encouraged and assisted to pass from the local classes to the district Colleges and from there to the University; and a complete co-ordination of the whole system of mining education from bottom to top should be attained.

The importance of technical education in mining in the past has not been sufficiently realized, with the result that the industry as compared with others has suffered. The industry of the future will be of much greater complexity and difficulty than in the past, and a higher technical education for those controlling it will be required.

The industry in the past has too often been carried on at a low standard of efficiency, and it should give proof of its belief in the value of highly-trained men by adequate moral and financial support, and by encouraging students in sufficient numbers. The problem is to produce a number of persons for each of the different grades of employment sufficient to meet not only the demand but the needs of the industry.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 94.

Workmen.—The workman will obtain his principal education at a public elementary school. On reaching the highest standard and commencing work at 14 years of age, he should continue his attendance at continuation classes under the new Education Act until 16, and later 18, for which the necessary facilities should be provided, taking in those two years the preliminary technical courses as arranged by the local education authorities.

Officials.—In considering the training of the official classes, one needs at once to distinguish between the future official who is rising from the practical side and the one who is coming direct from school. In other branches of engineering, institutions are free to make such regulations as to education as they deem best, but in coal-mining regard has always to be had to the provisions of the Coal Mines Acts respecting firemen, under-managers, managers, and surveyors—not only with regard to the subjects for examination, and the standard to be attained, but also with regard to the period and kind of practical work which is an essential qualification for candidates for these certificates.

Firemen.—The workman desirous of becoming a fireman will begin to specialize, and while attending his daily work will take at the local mining classes the first and second year's mining courses, passing the Home Office examination for the Fireman's Certificate at 25 years of age.

Under-managers.—Promising practical mining students desirous of going forward and becoming under-managers will, while still attending their daily work, take at the local mining classes the third and fourth year's mining courses as provided by the local education authorities, passing the Home Office examination for the Second Class Certificate of Competency as an under-manager at 23 years of age.

Managers.—Practical students desirous of going forward and becoming managers will, while still attending their daily work, take, either at the local mining classes (where facilities are available) or at the district Mining Colleges, the fifth year's mining course, passing the Home Office examination for the First Class Certificate of Competency as a colliery manager at 23 years of age.

The county and local authorities should encourage their most promising students to go forward from the local classes to higher studies at the district Colleges and pay fares and fees in these cases. The scholarships offered by the local education authorities and other bodies should also be increased, both in number and value, until it will no longer be possible for a boy to be prevented by financial reasons from receiving a University training. It should be made clear to all that there is no position to which a capable student may not aspire.

Colliery Mechanical and Electrical Engineers.—The training of these classes of officials is outside the present discussion; they will be prepared by taking the usual theoretical and practical courses necessary to properly qualify them for their future work.

Students.—We may now consider the student coming into mining direct from a public school. Youths who have this advantage will be well advised to matriculate before leaving, in order to qualify themselves for entrance to the University.

Surveyors.—The student intending to become a surveyor may enter upon his career direct from school through a regular pupilage with a mining engineer, or at a colliery, or by taking the day courses in surveying at a Mining College, passing the Home Office examination for the Surveyors' Certificate as soon as he is qualified and able to do so; or he may take it at the same time as his examination for the First Class Certificate of Competency.

General Managers, Agents, and Mining Engineers.—It is to the University or to the Technical College of University rank that we must look for the adequate training of future managers of the largest concerns, agents, mining engineers, and Inspectors of Mines. The manager of a large colliery has great responsibilities. He must be able to initiate, consider, and decide upon proposals for working both seams that hitherto have been neglected as unprofitable and seams at greater depth, for generating power and distributing it electrically to distant points, or for the installation of plant for the distillation of coal and the recovery of bye-products, etc.; in fact, the successful development of the coal-mining industry demands not only the expert in various branches of engineering or of chemistry, but also the manager with a large outlook, a wide knowledge, and a far-reaching policy. The control of an industry of this importance not only justifies but demands an adequate training, since any failure to make the best use of our mineral deposits can never afterwards be remedied, and also because an improvement in mining methods may give so large a proportionate return.

A pupil of this class should remain at a public school until 18 years of age, and leave after passing the matriculation or equivalent examination. He should then spend twelve months working underground in a mine, when he should enter a University or a Technical College of University rank in order to take the full-time degree course.

There is little doubt in all applied studies that the sooner a pupil gets into contact with the industry he intends to enter the better. By doing so he is more capable of taking an intelligent interest in the instruction given. If he is the right kind of boy, the practical experience he obtains will make him take up the theoretical part of his training with greater zest; while if he is not the right kind of boy, he will probably find the work distasteful and seek a more congenial occupation.

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I have throughout assumed that instruction of an elementary character may be given in evening or Saturday classes, but that studies of an advanced nature should always be taken at day courses. Day study is always more profitable than evening study, and it will be for the good of the profession to encourage day work at the University and Technical Schools.

Mr. S. C. Laws (Wigan): My experience of mining education suggests that full-time courses of technical training should be much more extensively followed by those who are destined to occupy the most responsible positions. At the present time the industry very largely accepts the minimum required by the Coal Mines Act in the form of the First Class Certificate of Competency as evidence of adequate preparation for practically all forms of employment. As in other industries, positions of responsibility in which momentous and often immediate decisions have to be made from day to day and hour to hour can only be adequately filled by men who are able to combine an ample technical knowledge with a brisk mentality and wide outlook, a combination to the development of which years of study under suitable conditions may usefully be spent. Probably if the full-time courses in mining provided by Universities or Technical Colleges were more definitely associated with the industry in the way that is being begun in South Wales, for example, these would more readily command attention and confidence. Thus a boy who leaves the secondary school at 17 years of age and becomes a mining apprentice could spend a year at the colliery, attending part-time classes meanwhile, before entering upon the first year of his full-time mining course. If this latter were to occupy four sessions each of six months' duration, the apprentice would be able to complete this and obtain nearly four years' practical experience before completing his apprenticeship and securing his Home Office Certificate at 23. With this system in operation, the full-time mining course would fall into its proper place as an essential part of apprenticeship. And just as a progressive and suitably organized course of study is essential to progress on the technical side, so at the mine the apprentice should be enabled by a due allocation of his time throughout apprenticeship to gain a well-balanced experience of all aspects of mining work. Moreover, in view of the necessity in the national interest that the mining industry should secure the fullest possible use of the best brains in whatever station of the social order these are to be found, it is essential that there should be a more adequate supply of scholarships to the full-time mining course. Holders of such scholarships should receive a practical training similar to that suggested for apprentices.

For the minor official positions part-time courses of technical training should continue to apply. By the Education Act of 1918, however, these will undergo an enormous and fundamental development. A few years after the adoption of this Act all mine employees, in common with other young persons, will be required to attend schools for 320 hours in each year until 18 years of age. Moreover, this attendance is to be made during ordinary working hours, and not, as has been usual hitherto, at the end of the day. With the system of part-time day schools in operation, it would appear an obvious step for the industry to provide for a continuation beyond the age of 18 years of day classes—say, on one day per week—in the way of specially-selected young persons: in this way would be created a trained supply of workers from which to recruit the minor official positions.

Dr. GEORGE HICKLING (Manchester): My remarks must be regarded merely as those of an onlooker and not of an expert. One point on which I think everyone is agreed is the fact that the training of the colliery manager must be of the widest possible character; and such remarks as I make will be directed towards indicating slightly the part which, in my opinion, the Universities might play in providing for such an education. The valuable communication sent by Sir John Cadman* seems to indicate the principal difficulty which has caused some confusion in the discussion of this problem, namely, that while it is clearly desirable that facilities should be provided by which a man may pass from the lowest to the highest positions in the colliery, it must nevertheless be recognized that the training required for different types of mine workers is essentially different in character. For the practical purposes of educational organization three fairly well-marked grades may be recognized: first, that of the miners up to the grade of firemen; secondly, under-managers and pit managers; thirdly, the general managers and agents. With regard to the first two, the training which is absolutely essential to their work appears to me to be primarily technical in character, and is probably to be most effectively provided in the various technical classes and institutions which exist for that purpose. On the other hand, the third group requires an altogether wider training. While the general manager must naturally possess the technical knowledge required by other officials, and indicated by the requirements for the mine-manager's certificate, the problems which mainly claim his attention are becoming ever wider in scope. The day when it was sufficient for the colliery manager to choose from the seams under his control those which could be worked at the greatest profit and to work those on traditional lines, merely disposing of the output at the highest price which he could obtain, is rapidly passing. The actual process of mining is becoming more and more a highly specialized branch of mechanical engineering. The increasing application, for example, of electrical power in mining operations is making it evermore necessary that the colliery manager shall be competent to enter into an informed discussion as to the relative merits of different designs of electrical machinery. Therefore, while it cannot be possible that among his many other attainments the colliery manager shall be an expert electrical engineer, it is clearly desirable that a part of his training shall have been acquired in some institution where he could come into contact with those whose business it is to design electrical machinery and more especially to study the fundamental principles underlying such design. To refer, again, to another question, the proper utilization of coals is rapidly rising in importance. It is no longer sufficient to consider coal merely as a fuel: it has now to be regarded still more as a source of the most valuable bye-products. Seams which were formerly neglected must now be regarded as national assets of the highest value, and it becomes the duty of the directing manager of the colliery to see that all the seams in his royalty are utilized in the most effective manner. The study of the coals themselves must be primarily the work of the coal chemist; and, again, it is obvious that the colliery manager cannot be expected to possess the detailed knowledge of the highly specialized branch of organic chemistry which is essential to this study; but it is also clear that he should be in a position fully to appreciate and intelligently to discuss the work which the chemist does on his behalf. For this purpose again it is clearly to be desired that the manager shall receive some of his training in an institution where such work is in progress and where he may learn something of its methods and underlying principles, although he himself cannot spare the time necessary to acquire the mass of detailed information essential to the actual conduct of chemical investigation.

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* See *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 163.

The two points which have been mentioned may suffice to indicate to some extent the way in which a training in an institution of University character should be of the highest value to the general manager of a colliery. Many other illustrations of similar type will doubtless occur to the members present. In conclusion, while the advantages of such a training are clearly desirable for the man who from the outset is definitely destined to become a general manager, it is also to be remembered that the same advantages should be open to any colliery official whose capabilities and ambitions may lead to the hope that he will some day be able to rise to that position.

Mr. JOHN GERRARD (Worsley): Speaking generally, if there is an awakening to the greater value of scientific mining, then, surely the mining industry must not be behind. We must devote attention to the needs of those who work in the mines, of those who will become mining officials, and of those who will be managers and mining engineers. To the last class should be available the highest University or College education. Employers will have to show a wider appreciation of the value of University rank.

Mr. ARTHUR MILLER (Pendlebury): With regard to the question of heredity in the mining profession, I think that when a mining man gets to 50 or 60 years of age you will not find him putting his son to mining unless it is an exceptional case, and he is in an exceptional position for giving him a good professional training. With respect to the suggested division between managers, agents, and mining engineers, when I look round I fail to see that there is any real division between the managers and the agents. Nearly all the latter have been managers, and I do not think that they obtained any further scientific training except what they got in connexion with their work; but I should judge that they have studied psychology to some extent and understand human nature. They are able to turn that knowledge to some use. But how can we start with three divisions? How are we to know at the start who will prove to be the best man?

We are altogether behind in the standard of knowledge that is required. Take the case of the firemen's examination. What is it? Something that a schoolboy could pass, nothing more nor less. We must, of course, have these certificated men, but I say deliberately that every youth who proposes to become a fireman should be able to pass an examination equivalent to a matriculation examination. He would do it if he could see before him sufficient encouragement, something which would make it worth his while to pass it. If this country is to fight successfully its competitors abroad, adequate remuneration must be given for scientific knowledge and training.

The PRESIDENT (Mr. A. J. A. Orchard): The subject has been fairly discussed and there is general agreement that increased facilities for training mining students are required. The particular order of training is not at the present stage in Lancashire so urgent a problem as the question of organizing and co-ordinating existing schools, which require linking up with the industry on the one hand, to ensure the supply of students, and with the University on the other, so that the industry may ultimately benefit from the highest class of teaching.

Mr. DAVID E. THOMAS (St. Helens) wrote: One outstanding feature in the education of the mining student is the almost general absence of co-operation and co-ordination of efforts between education authorities and the mining industry. The interdependency of the theoretical and practical training must receive fuller consideration. It must be more fully recognized that any scheme for the training of mine officials must be of a dual character: the practical side of the training must be co-ordinated with the theoretical.

In the past our evening Technical Schools, full-time Mining Colleges, and Universities have struggled along on their own initiative, and, with the exception of one or two cases, confined themselves entirely to the theoretical training of mine officials.

Numbers of evening students at Technical Schools, through sheer grit and ability, have forged their way upward, by the help of scholarships granted by education authorities, and obtained their diplomas in our Mining Colleges and Universities, in many cases obtaining their B.Sc. Degree in Mining Engineering. The Colliery Manager's First Class Certificate was an easy matter for them to obtain, yet in many cases these men had to consider themselves fortunate if they could obtain posts as colliery firemen when they had completed their College education. It may be said, and quite rightly so, too, that in many cases these young men were not practically capable of taking on higher posts. If, however, their practical training for work of an official character had been properly co-ordinated with their theoretical training, the industry would benefit by their talent many years earlier.

The aloofness existing between the industry and education authorities is almost as glaring even in the case of the "articled pupil." He may enter on a University Course of training, but the nature of the training he may receive at the Mining School or University is apparently a matter of indifference to the colliery company, and, *vice versa*, the College authorities have very little interest in his work at the collieries. The condition of things is a matter of easy solution. It is a waste of effort to formulate schemes which do not recognize the essential necessity of close co-operation and co-ordination between education authorities and the industry.

Local education authorities should be asked to co-operate with the local mining authorities, and labour leaders if desirable, to form a Mining Education Committee. This Committee should deal with all matters relating to the mining education in the area involved. Periodical reports from the responsible organizer of mining instruction would come under their consideration. The Committee should make the necessary provision whereby promising students could be selected for scholarships ensuring a part-time course of study of one day per week at the school, with suitable training at the collieries. In the more exceptional cases, where a student has passed the matriculation examination and is likely with training to become an efficient mining engineer, there should be available a scholarship to some University, combined with a system of apprenticeship, and tenable for a number of years. Where a student in the course of his higher training leaves the local mining area, his career should come under the supervision of a Mining Education Committee selected on a wider basis. Mining students would thus be brought under the intimate care of the industry, and the industry itself would benefit by better trained men.

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

Held at the University, Edmund Street, Birmingham, December 16th, 1918.

Mr. WILLIAM CHARLTON, President, in the Chair.

DISCUSSION OF PROF. F. W. HARDWICK'S PAPER ON "THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION."*

The **President** (Mr. William Charlton): This paper may be regarded as one of the consequences of our war-period experiences. During that trying time our national characteristic of ability to improvise, meet, and overcome entirely new and unprecedented conditions has been strikingly demonstrated. At the same time, it has revealed grave defects in our national systems of education and social organization. In many directions, and in particular in the engineering professions, there is a strong and wide-spread impulse to remove causes of reproach and give to future generations the highest and best possible equipment for the pursuit of the arts of peace and industry. Prof. Hardwick's paper is in no sense didactic. It is rather intended to be provocative of discussion, in the hope that from the recital of numerous experiences and opinions some generally-accepted policy may be evolved. I am at one with Prof. Hardwick and others who have already spoken on the subject in hoping that the policy agreed on may be of a liberal and wide character, so as to give opportunities to talent from all sources to exercise its abilities and rise to the highest positions in the mining profession.

It will be well that, in shaping our action for the future, we should follow the tradition of continuity of policy. We have no desire to disparage past methods and experience, but rather to benefit by their lessons. The one outstanding feature of my experience as a teacher and organizer is that we have endeavoured to erect a structure of scientific and technical knowledge on an inadequate foundation of general education. I have watched with pain and admiration how many men who now occupy positions of importance in the colliery world have struggled and suffered under a great handicap, and I am quite convinced that any future plans for technological education will be measured in their success by the efficiency of our elementary and secondary education systems.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 94.

Mining education in the past has been dominated by the requirements of the various Coal Mines Acts, which in succession have stated the conditions for the acquisition of First and Second Class Certificates of Competency. The general legislative policy in framing the particular sections of those Acts referring to this subject has been to leave a fairly wide open door, so wide as to admit to the examination-room both the University graduate with three years' mining experience and the miner with five years' practical experience underground. This has given rise to a wide diversity in methods of acquiring the necessary preparation for these examinations—self-preparation, private instruction, correspondence lessons, evening classes of various characters, some of quite an unorganized character. In the last 25 years some of the county councils having jurisdiction in coalfield areas have gradually developed systematized courses of instruction, which in their completeness, so far as the provision of instruction is concerned, may almost vie with Technical Colleges and Universities. Some of the modern Universities, and in particular that of Birmingham, have not been so limited in their curricula, which have been based on a more generous scale and wider outlook.

However circumscribed mining education may have been by the domination of the requirements of the Coal Mines Acts' Examination Boards, it still remains an almost unquestioned axiom that the entrance to the highest practice of the mining profession is by means of the colliery-manager's certificate. That being so, it appears to me that any alterations suggested should take the direction of improving the character of those examinations, in order that their reflex influence on educational work may satisfy the highest and best interests of the mining industry.

I have already indicated my opinion that a superstructure of scientific and technical knowledge can only be satisfactorily built up on a foundation of good general education, and if I am right—and it is an opinion based on a quarter of a century's specialized work in mining instruction—the whole subject we are now discussing must be related to the elementary and secondary education policy and systems of the country; interest in these by the mining community is, therefore, of vital importance, as it forms an integral portion of mining education.

A good foundation and excellent superstructure having been decided on, there remains the completion and coping-stones to be added. These may be the higher Technical Colleges, and part-day time courses of the County Council schools and Universities. It appears to me that the time has arrived when industry should contribute on a generous scale to the provision of scholarships, maintenance of students, and equipment of laboratories. Examples are already provided in South Wales, and I believe embryo schemes are in existence in other coalfields towards this end.

Mr. John Brindley (Wolverhampton): I do not find any reference in the paper to what, in my opinion, is an important point in the education and training of a mining engineer. I allude to the question of splitting up the education and concentrating on only one or two of the various branches of mining. It is unreasonable to expect a mining engineer to have a complete knoweldge of all these various branches, each of which needs practically a life's study, and I would suggest that students should take up one particular branch only, acquiring, of course, a general knowledge also of other branches. For instance, there is the managerial side of mining, such as the consideration of the general policy and lay-out of a mining property in accordance with the leases and agreements. Then there is the important legal side, dealing with the multiplicity of rules, forms, regulations, compensation claims, etc. Again, there is the purely engineering side—steam, electricity, ventilation, haulage, pumping, and so forth. Many of these branches call for expert knowledge, and in my opinion the reason why the results of mining operations in this country do not compare favourably with other countries is in some measure due to a lack of expert knowledge in many cases. A little knowledge is very often dangerous, where, on the other hand, expert knowledge of the subject would have produced satisfactory results.

Prof. Sir W. J. Ashley (Birmingham University): Prof. Hardwick's paper does not profess to give much in the way of suggestions with regard to the course of training. The author limits himself to urging that the time has come when systematic information should be collected afresh as to the courses of training now available, and as to the various educational bodies which deal with the training of mining engineers. On the face of it, it would seem to be very necessary for students and their parents to have access to recent and reliable information. This, however, after all, is a comparatively simple matter; your Secretary could probably prepare such a statement in a week or so. But it is likely that the time has come for something more than that; and I think it would be worth while to get the opinions of men who are actively engaged in various branches of the profession as to what constitutes a *desirable* education.

The manager of to-day has a range of duties wider than the manager of twenty or thirty years ago. The aggregation of mining properties, as, for instance, in South Wales, has made a great difference. Evidently the training of men should be directed to the duties which they will be called on to perform; and three questions occur to me. Mining students must be informed as to mining practice; and must also be taught a certain amount of chemisty, physics, etc. But *how much* chemistry, physics, or engineering should be included in their courses, and of what kind? Then there is the question of the management of labour, which opens up a very wide field. I do not know whether there is anything in existing courses of instruction to cover this. And, thirdly, there is business policy, and the whole question of costs in relation to output and price, to which it is very desirable that those who are to be concerned with the commercial management of a colliery should give painstaking attention. Let me add that I entirely agree with what your President has said as to the desirability of building the strictly professional education on top of a good general education. It should be realized that matriculation does not represent by any means a high standard, and any boy who has been reasonably well educated at a secondary school should be able to pass it.

Mr. T. G. Bocking (Birmingham): There are many points deserving consideration, but the two which I wish to refer to are as follows:—

(1) *The Pupilage System.*—The systems of pupilage in vogue at Rother Vale, Dalton Main, and other collieries are excellent, but might be greatly improved by an interchange of pupils with collieries all over Great Britain, and even on the Continent. This would enable the pupil to obtain an insight into systems of mining which he could not obtain at one colliery only.

(2) *Surveyors.*—A similar interchange of surveying pupils would be an advantage, as very often the experience at one colliery only is insufficient. My firm gives surveying pupils the advantage of getting experience of every kind of surveying all over the country.

The training required for a surveyor's certificate is absolutely ridiculous and insufficient, and the statements entered on the certificate are not necessarily correct. The examination does not ascertain the candidate's competency. A higher examination and a higher-class certificate is badly needed to improve the status of surveyors and to give the highly-qualified surveyor a better means of recognition.

Mr. L. Holland (Hamstead): The training of coal-mining students is an important question. Mining requires more practical experience than any other profession. Nearly every mine has some special physical character of its own, which makes the mining problems of one pit different from those of another, and there is very little comparison between the working of mines in different parts of the country.

The theoretical training is necessary to enable the student to make the best and fullest use of what he encounters in actual practice, and on this training depends his ability to face the scientific problems of mining. But in my opinion the present qualifications laid down by Government Regulations do not (*a*) tend to bring in the best men, nor (*b*) do they tend to the best training, nor (*c*) are they fair to the individual.

(*a*) How many parents whose boy has distinguished himself at school would send him to the University for three years, with a prospect of two years' work at the face, and then have no position in prospect, when they can choose other professions with a certainty of a position at the end of his training?

(*b*) If a student attends the University for three years, with occasional visits to a mine, his learning at the end of that time is based on faith and not on experience, and is really equivalent to cramming for an examination. When he takes to pitwork at the face, his experience is too local and narrow, and he must wonder why he spent valuable years of his life in studying the mechanical, electrical, surveying, and coal-screening theories of mining.

(*c*) From his point of view the practical side as it presents itself in reality may not appeal to him, and either he may not be able to take the interest so absolutely necessary, or he may be disappointed and give up the profession for something less arduous.

If a boy matriculates and goes to a colliery for six months, he would have an idea of what a coal-mine is, and why mechanical, electrical, and other training is necessary. He should then be allowed to put in half-time at the University and half-time at the colliery, and his theory and practice would grow together as part and parcel of each other: one would aid the other and give interest to the student. After completing his course he should be able to take a position that would enable him to pick up some experience in the methods of dealing with men, of laying out roads and haulage, and to have sufficient experience in the actual workings to know when a place is safe or unsafe, and whether the coal is being worked in the best way. The actual work of loading or packing, timbering, stonework, etc., passes the Home Office standard of qualifications; but who would entrust the responsibility of a mine to a man who had no more experience to his credit than this?

The student should have the opportunity of assisting the management in making plans for alterations to any machinery, both surface and underground, or in laying out a district, the working-out of costs, output per man employed in different districts and stalls, ventilation, etc. This would bring him into actual contact with some of the problems of management; and finally he should be given responsibility as deputy or overman, where he would learn to deal with men, actual mining difficulties, haulage problems, supply of tubs and materials to the working-places, etc. This work would show up his capabilities and grit or otherwise, and if he gave satisfaction he would have little difficulty in obtaining eventually a position as manager.

Unfortunately, the idea of many students is that a University degree or a colliery-manager's certificate is all that is needed to obtain a manager's position. It cannot be too strongly impressed on the student that practical experience is the main thing, and the theoretical training is the means by which he will be able to improve and make best use of his practical knowledge. It is impossible for a mining student to graduate in mechanical and electrical engineering, but he needs as much as his brains and time will allow him to absorb both in lectures and in the shops. A pupil should have sufficient opportunity for putting in a short period of time in the fitting and electrical-engineering shops.

Another type of mining student is the practical miner who shows ability and ambition. Facilities should be given him to attend technical classes, and, if need be, county scholarships should be available for him. He needs every encouragement. Managers as a rule are not slow to recognize his ability, because they look to such men to fill the underground official positions.

Mr. J. HUNTER (Cannock): Some of the members have referred to the basis of building-up in regard to mining education, and this is a highly important matter. I am aware that there has been considerable improvement in this respect in the last decade, and I trust that there will be further improvement. The mining profession is of the greatest importance to this country, and the Government should give it more recognition. At the present time men have not the opportunity to carry their education far enough on account of the expenditure. Facilities for training are unequal in different parts of the country. There is a Mining School at most Universities, but the expenses are very heavy; there are not enough opportunities to obtain scholarships, and the Government should therefore provide them. I feel strongly that better facilities for study and training should be given to working-class students, for they generally get a good practical training. I agree with Mr. Brindley in the necessity for dividing the duties of a colliery manager, and believe that this is being done in many large concerns by the appointment of a mechanical engineer, electrician, surface manager, etc.; but it must not be forgotten that the responsibility always remains with the colliery manager, and it must be borne in mind that colliery undertakings are now much larger than they were in the past.

Lieut. G. N. SCOTT (Birmingham): The point is raised in the paper whether students should spend a year or nine months at a colliery before commencing their mining education. In my opinion it is very desirable that they should do so, otherwise many matters would be like Greek to the student of a University unless he had had some previous underground experience.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM DEC. 1ST, TO DEC. 28TH, 1918, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of		Magnetic character.	Intervals in hours (Greenwich mean time).												
Week.	Month.		0h. to 2h.	2h. to 4h.	4h to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h.	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
	Dec.		14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
Sun. ...	1	2	45′·0	46′·0	47′·5	47′·0	46′·0	48′·5	50′·5	50′·5*	43′·0*	39′·5*	33′·0*	36′·0*	44′·5
Mon. ...	2	0	44·0	47·5	47·0	46·0	45·5	47·0	48·5	48·0	47·0	45·5	44·5	45·5	46·5
Tues. ...	3	1	46·5	46·5	46·5	46·5	48·0	51·5	50·0	52·0	49·0	45·5	39·5	42·5	47·0
Wed. ...	4	0	45·0	46·0	45·5	45·5	46·0	48·0	48·0	48·5	47·5	45·5	43·5	44·5	46·0
Thur. ...	5	0	45·5	45·5	45·5	45·0	46·0	47·5	47·5	47·0	46·5	45·5	45·0	45·0	46·0
Fri. ...	6	0	45·5	46·0	46·0	45·5	46·0	48·0	47·5	47·0	46·5	46·5	45·5	45·0	46·5
Sat. ...	7	2	46·0	45·5	45·5	45·0	47·0	47·5	48·5	48·5	49·5	40·5*	40·0*	38·0*	45·0
Sun. ...	8	2	36·5*	38·0*	45·0*	50·5	51·0	54·5	58·0*	53·0*	47·5*	44·5*	39·5*	36·5*	46·0
Mon. ...	9	2	45·0	48·0	47·0	48·0	48·0	51·5	51·5	47·5	44·5	39·0*	39·5*	43·0*	46·0
Tues. ...	10	2	45·5	45·5	47·5	49·0	50·0	50·0	48·5*	46·0*	43·5*	44·5*	42·5	43·0	46·5
Wed. ...	11	2	45·5	45·0	46·5	47·5	46·5	47·0	48·5	45·0*	45·0*	39·5*	40·5*	41·5*	45·0
Thur. ...	12	1	45·5	48·0	48·0	47·0	45·5	47·0	48·0	47·5	46·5	43·5	43·5	44·0	46·0
Fri. ...	13	2	45·5	47·0	47·0	46·5	46·0	48·0	50·0	47·5	42·5*	45·0*	39·0*	43 0	45·5
Sat. ...	14	1	45·0	46·0	46·5	46·5	48·0	48·0	49·0	49·0	48·0	46·0	44·5	43·5	46·5
Sun. ..	15	0	46·5	47·0	46·0	47·0	47·5	49·0	49·5	49·0	47·5	46·5	45·5	46·0	47·0
Mon. ...	16	0	47·5	47·0	45·5	45·5	46·0	48·5	50·5	50·5	50·0	46·0	43·0	45·0	47 0
Tues. ...	17	1	47·5	47·0	45·5	46·0	47·5	49·0	49·0	48·0	45·5	43·5	44·5	45·5	46·5
Wed. ...	18	0	46·5	46·5	45·0	45·0	46·5	48·0	48·5	47·0	47·0	46·0	44·5	42·5	46·0
Thur. ...	19	1	41·5	41·0	42·0	45·5	48·0	50·5	53·0	50·5	49·0	49·0	44·0	44·5	46·5
Fri. ...	20	1	45·5	46·5	46·0	46·0	46·5	48·0	49·0	49 0	47·0	45·5	45·5	42·5	46·5
Sat. ...	21	1	45·0	46·0	46·0	46·5	47·0	48·5	47·5	48·0	49·0	43·5	45·0	45·0	46·5
Sun. ...	22	1	44·0	43·0	43·5	45·0	46·0	47·0	47·0	47·0	47·0	45·5	41·0	44·0	45·0
Mon. ...	23	1	44·5	42·5	43·5	45·5	47·0	48·0	47·5	48·0	46·0	44·5	41·5	41·5	45·0
Tues. ...	24	1	45·0	46·0	45·0	45·0	46·0	48·0	49·5	48·0	47·0	45·0	44·5	44·0	46·0
Wed. ...	25	2	45·0	45·5	46·0	49·5	47·0	48·0	50·0	53·0*	46·5*	34·5*	30·5*	42 5*	45·0
Thur. ...	26	2	48·5*	45·5	45·0	47·0	47·0	49·0	49·0	48·0	42·5*	37·0*	33·5*	40·0*	44·5
Fri. ...	27	1	43·5	44·5	44·0	45·0	45·5	47·0	46·5	45·5	45·0	45·0	45·0	45·0	45·0
Sat. ...	28	0	45·5	45·0	45·0	45·0	45·0	47 ·0	47·5	47·0	45·5	45·0	44·5	44·5	45·5

Diurnal Inequality (i.e., departure from mean value for day).

	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.
December, 1917 ...	−0′·7	−0′·8	−0′·6	−0′·3	−0′·5	−0′·7	−1′·1	−1′·8	−2′·6	−1′·3	+0′·5	+2′·2
November, 1918 ...	−0·9	−0·6	−0·3	−0·2	−0·9	−1·3	−1·4	−1·6	−1·6	−0·1	+2·4	+4·3
November, 1917 ...	−0·9	−1·0	−0·6	−0·3	−0·7	−1·2	−1·9	−2·8	−2·9	−1·5	+1·4	+3·1

	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
December, 1917 ...	+3′·6	+3′·6	+3′·0	+2′·0	+0′·8	+0′·3	0′·0	−0′·5	−1′·3	−1′·8	−1′·2	−0′·8
November, 1918 ...	+4 4	+3·8	+2·9	+2·1	+1·0	−0·1	−0·9	−1·6	−2·4	−2·6	−2·6	−1·8
November, 1917 ..	+3 3	+3 2	+2·8	+2·0	+0·8	+0·3	0·0	−0·1	−0·7	−0·9	−0·8	−0·9

* Large disturbances during this interval.

Mean Value for Month.

December, 1917.	November, 1918.	November, 1917.
14° 55′·5.	14° 46′·9.	14° 56′·6.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM DEC. 29TH, 1918, TO JAN. 25TH, 1919, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of Week.	Day of Month.	Magnetic character.	0h. to 2h.	2h. to 4h.	4h. to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
	Dec		14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
Sun. ...	29	0	46′·0	46′·0	45′·5	45′·0	45′·5	47′·0	48′·0	47′·0	45′·5	45′·0	45′·5	45′·5	46′·0
Mon. ...	30	0	45·5	45·5	45·5	45·0	45·0	47·0	47·0	46·5	45·5	45·0	44·5	44·5	45·5
Tues. ...	31	1	45·5	46·5	45·5	45·0	45·5	47·5	50·0	49·5	47·5	44·0	43·5	44·5	46·0
	Jan.														
Wed. ...	1	0	45·0	45·5	44·5	45·0	45·5	47·0	48·0	47·0	47·0	46·0	44·5	43·5	45·5
Thur. ..	2	0	45·0	45·5	45·0	44·5	44·5	46·5	47·0	46·0	45·5	45·0	44·5	44·5	45·5
Fri. ...	3	2	45·5	45·5	45·5	45·5	45·5	46·5	47·5	46·5	46·5	42·5*	31·5*	46·0	44·5
Sat. ...	4	2	40·5*	39·5*	44·5	45·0	48·0	52·5	54·0	50·0	45·0*	37·5*	38·0*	37·0*	44·0
Sun. ...	5	2	41·5	48·0	49·0	49·0	50·0	50·0	48·5	47·0*	37·0*	40·5*	40·5*	42·5*	45·0
Mon. ...	6	2	45·5	47·0	45·5	45·5	46·5	48·5	48·0	45·5	45·0	43·0	40·0*	45·0*	45·5
Tues. ...	7	1	45·5	47·0	45·5	46·0	46·5	47·0	47·0	47·5	45·5	43·5	43·0	44·5	45·5
Wed. ...	8	1	44·5	45·5	46·0	47·0	46·5	47·0	48·5	46·0	45·5	45·0	43·5	42·5	45·5
Thur. ...	9	0	43·0	45·0	45·5	46·0	44·5	46·5	47·0	46·0	45·0	44·0	44·5	44·5	45·0
Fri. ...	10	0	45·0	45·0	45·0	44·5	43·5	47·0	48·5	47·0	45·5	45·0	43·5	44·0	45·5
Sat. ..	11	0	45·5	45·5	45·0	44·5	44·5	47·5	48·5	46·5	45·5	44·5	44·5	44·0	45·5
Sun.	12	0	44·5	45·5	45·0	44·0	44·5	47·5	48·0	47·0	46·5	45·0	44·0	45·0	45·5
Mon. ...	13	1	45·5	46·5	47·0	50·0	51·0	50·5	49·0	48·0	47·5	48·0	44·0	44·5	47·5
Tues. ...	14	1	44·5	44·5	45·0	49·0	45·0	46·5	48·0	47·5	46·0	44·5	44·0	44·0	46·0
Wed. ...	15	1	45·5	46·0	45·5	44·5	43·0	46·0	48·5	49·0	47·5	45·5	41·5	40·0	45·0
Thur. ...	16	2	44·0	44·0	44·0	44·5	44·0	47·5	51·5	51·5	49·5	44·0*	36·0*	39·5*	45·0
Fri. ...	17	2	44·5*	46·0*	43·0*	47·5*	46·0	48·5	49·0	49·0	45·5	40·5*	36·5*	43·0*	45·0
Sat. ...	18	2	42·5*	43·0*	44·5	46·0	48·0	48·5	49·0	48·0	40·0*	38·5*	36·5*	38·5*	43·5
Sun. ...	19	2	42·0*	44·5*	44·0*	44·0	45·0	46·0	48·0	47·5	43·0*	41·0*	41·5*	42·0	44·0
Mon. ...	20	1	43·0	44·5	45·0	44·5	45·0	46·5	48·5	49·0	46·0	44·0	42·5	42·0	45·0
Tues. ...	21	1	41·0	45·0	43·5	44·0	44·0	46·5	48·0	47·0	45·5	44·0	40·0	42·0	44·0
Wed. ...	22	1	44·5	44·0	44·5	44·5	43·5	45·5	48·0	48·5	46·0	43·0	42·0	42·5	44·5
Thur. ...	23	1	43·5	43·5	42·5	43·5	44·0	46·0	47·5	46·5	45·0	43·0	42·5	43·0	44·0
Fri. ...	24	0	44·0	44·5	44·0	44·0	43·5	46·5	50·0	48·0	4 ·0	44·5	43·5	41·5	45·0
Sat. ...	25	0	43·5	43·5	42·5	43·0	43·0	45·5	48·0	47·0	45·5	45·0	44·0	44·0	44·5

Diurnal Inequality (*i.e.*, *departure from mean value for day*).

	1h.	2h.	3h.	4h.	5h.	6h	7h.	8h.	9h.	10h.	11h.	12h.
January, 1918 ...	−0′·9	−0′·6	−0′·2	+0′·5	+0′·2	−0′·4	−0′·9	−1′·5	−1′·8	−1′·6	+0′·5	+2′·2
December, 1918 ...	−0·5	−0·3	−0·1	−0·5	−0·8	−0·6	−0·4	−0·3	+0·1	+1·2	+2·1	+2·4
December, 1917 ...	−0·7	−0·8	−0·6	−0·3	−0·5	−0·7	−1·1	−1·8	−2·6	−1·3	+0·5	+2·2
	13h.	**14h.**	**15h.**	**16h.**	**17h.**	**18h.**	**19h.**	**20h.**	**21h.**	**22h.**	**23h.**	**24h.**
January, 1918 ..	+3′·1	+3′·4	+2′·4	+1′·2	+0′·4	+0′·1	−0′·2	−0′·6	−0′·9	−1′·4	−1′·7	−1′·4
December, 1918 ...	+2·6	+2·4	+2·0	+1·5	+0·9	−0·2	−1·0	−1·6	−2·6	−2·6	−2·1	−1·5
December, 1917 .	+3·6	+3·6	+3·0	+2·0	+0·8	+0·3	0·0	−0·5	−1·3	−1·8	−1·2	−0·8

* Large disturbances during this interval.

Mean Value for Month.

January, 1918.	December, 1918.	December, 1917.
14° 54′·8.	14° 46′·1.	14° 55′·5.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G.M.T.

Character "0" means a day wholly free from any but small disturbances.

,, "1" ,, ,, part or all of which is moderately or considerably disturbed.

,, "2" ,, ,, part or all of which is highly disturbed.

The normal value for an hour is the mean declination for that hour in the month, derived from quiet days only, or from all days excluding those of character "2." On a day of character "0" declination at any hour will usually be within about 3′ of the normal. On a day of character "1" the departure from the normal will usually not exceed 5′, but it may occasionally be as much as 10′, or even more. On a day of character "2" the departure from the normal will seldom exceed 20′, but departures of 30′, or even on extreme occasions of 1° or more, may occur.

The above values were obtained from measurements made after "smoothing" the curves.

THE INSTITUTION OF MINING ENGINEERS.

TWENTY-NINTH ANNUAL GENERAL MEETING,
HELD AT UNIVERSITY COLLEGE, NOTTINGHAM, SEPTEMBER 13TH, 1918.

MR. WALLACE THORNEYCROFT, RETIRING-PRESIDENT, IN THE CHAIR.

RECEPTION BY THE MAYOR AND SHERIFF OF NOTTINGHAM.

The Institution was welcomed on behalf of the City of Nottingham by the Mayor and Sheriff, and on behalf of the Midland Counties Institution of Engineers by the President (Mr. H. E. Mitton).

The RETIRING-PRESIDENT (Mr. Wallace Thorneycroft): On behalf of The Institution of Mining Engineers I thank you heartily for the words of welcome which you have spoken on this our visit to Nottingham. As Mr. Mitton has said, this meeting is curtailed, and we are here solely for business. Even our attendance is much less than usual, because our members are strenuously engaged in the work of raising coal. I can assure you that their efforts are being devoted to speeding up the production of coal to the utmost of their ability during this time of crisis. They are carrying out their duties as colliery managers and officials under very considerable difficulties, arising from shortage of men, shortage of machinery, and the adverse conditions generally under which mines are now being worked. Our difficulties are not decreased by the dual control —or, shall I say, the triple control—which is thought to be necessary, during this war. The responsibility of carrying on collieries is increased by the receipt of instructions—often a little ambiguous—from London. They are ambiguous of necessity when one man in London attempts to give instructions to every colliery district in Great Britain where the customs and conditions of working are widely different. In those circumstances we all do the best we can and make the innumerable returns asked for without grumbling. As President of this Institution, I do earnestly express the hope that every householder will do his best to " carry on " with the limited amount of coal which is allotted to him, and possibly to do with less by using timber. We have to supply Italy and France with coal, and, owing to the increasing number of Americans that are coming over, a considerable amount of coal is required to convey them from the sea-board to the scene of action. This is the fifth time we have met under war conditions, and we have not yet come to the end of the struggle. Things are, however, more hopeful at the present time, and we are beginning to see daylight at the end of the dark tunnel. I must repeat my hope that this time next year we shall meet under peace conditions, but whether that proves to be the case or not, we are going on until we win this war.

TWENTY-NINTH ANNUAL REPORT OF THE COUNCIL, 1917-1918.

The Council in submitting their Twenty-ninth Annual Report have much pleasure in stating that there has been an increase in the membership during the past year, the number of members at July 31st, 1918, being 3,268.

THE WAR.

The number of members now serving with His Majesty's Forces at the commencement of the fifth year of the war is about 457, exclusive of 64 members who have been killed in action or have died of wounds. Since the last report the following have been reported killed:—Lieut.-Cols. B. H. Charlton and F. J. Trump; Major R. G. M. Prichard; Captains G. F. H. Charlton, H. B. Holdsworth, G. B. Kay, G. H. S. Kent, A. L. Mann, Adam P. Nimmo, C. F. B. Simpson, T. A. Thirlwell, F. A. Thornton, F. M. Weeks, and H. R. Wilson; Lieuts. W. E. Avery, Norman Bedford, and Ernest J. Phillips; 2nd Lieuts. Hugh C. Annett, C. P. Almond, and H. H. Potts; Sergeant Charles Young, Corporal George Jacobs, Sapper Samuel Coade, and Trooper James Heslop.

The Council tender their sincere sympathy to the relatives of these members in their bereavement, and desire to place on record their high appreciation of the gallantry and devotion of those who have laid down their lives for their country.

During the year the following rewards and distinctions have been conferred for gallantry in the field:—C.M.G.: Lieut-Col. Lionel E. Pilkington; D.S.O.: Col. Godfrey Jones, Lieut.-Col. Philip Kirkup, Jun. (bar), Majors Harry La Trobe Campbell, Herbert J. Humphrys, J. R. N. Kirkwood, John A. S. Ritson, Captains Sir H. Dennis Bayley, K. M. Guthrie, and F. R. A. Shiel; M.C.: Majors H. M. Hudspeth, Vernon Merivale (bar), P. H. Wain, Captain A. P. Nimmo, Lieuts. H. Ridley Dixon and R. C. Thomas; Croix de Guerre: Captain T. A. Thirlwell; Mentioned in Despatches: Lieut.-Col. F. I. L. Ditmas and the Hon. E. L. Wood.

Arnold Ratcliff (Librarian and Stockkeeper) has joined the Army Service Corps, Percy A. Hawtin (Assistant Librarian and Stockkeeper) the London Rifle Brigade, and Frederick Cave (Junior Clerk) the Essex Regiment. The last has been wounded in action.

OBITUARY.

The Council regret to record the death of the following civilian members during the year:—His Grace the Duke of Northumberland, K.G., a Past-President of the Institution, Sir John Wilson, and Messrs. John W. Ainsworth, Philip Archer, William Armstrong, Thomas Ashworth, Charles R. Barrett, Harris Bigg-Wither, George M. Cockin, A. H. Crichton, Daniel Cullen, Samuel Dean, William Dixon, James Douglas, Donald J. M. Downie, W. H. Draper, William Elliott, J. O. Greaves, Charles Henderson, W. D. Holford, Edward Hull, E. T. Ingham, Rokusaburo Kondo, John Lancaster, Charles Latham, Hugh Latimer, George A. L. Lebour, John M. Martin, Gerald L. Moss, Robert Peel, W. A. Ritson, Simon Tate, and John E. Tongue.

DISTINCTIONS CONFERRED ON MEMBERS.

The Council congratulate the following members on distinctions conferred upon them :—K.C.S.I.—Sir Thomas Holland; K.C.M.G.—Prof. John Cadman; K.B.E.—Mr. Adam Nimmo; M.B.E.—Mr. John Masterton; King Edward Medal for Bravery in the Mine—Mr. George S. Christie; Albert Medal—Lieut. F. Stuart Smith; Carnegie Medallion for rescue-work in mines—Mr. Henry Rowan.

PRESIDENT-ELECT.

Mr. George Blake Walker has been nominated as President of the Institution for the ensuing year.

INSTITUTION MEDAL.

The Institution Medal has been awarded to Mr. Charles Edward Rhodes for his eminent services to the science and practice of coal-mining during the past fifty years.

INSTITUTION REPRESENTATIVES.

The Institution representatives on the various bodies and societies remain the same as for last year.

Mr. Wallace Thorneycroft has been appointed the Institution representative on the Engineering Training Committee formed to consider the question of engineering training.

ADVISORY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH.

The sub-committee on "The Control of Atmospheric Conditions in Hot and Deep Mines" has presented an interim report on the work done during 1917, which has been forwarded to the Advisory Council for Scientific and Industrial Research, who provided the funds. This work is being continued, and it is hoped that in future further funds will be available to assist the Institution in carrying out other investigations, the results of which will in due time be published in the *Transactions*.

IMPERIAL MINERAL RESOURCES BUREAU.

The special committee appointed by the Government to examine the proposal for the establishment in London of an Imperial Mineral Resources Bureau have now reported in favour of the project. The Bureau will be incorporated by Royal Charter, and the first Governing Body will consist of Sir Richard Redmayne, K.C.B. (Chairman), seven representatives nominated by the various Colonial Governments, and six others (Mr. W. Forster Brown, Prof. H. C. H. Carpenter, Dr. F. H. Hatch, Sir Lionel Phillips, Bart., Mr. Edgar Taylor, and Mr. Wallace Thorneycroft) appointed by the Ministry of Reconstruction in consultation with the Institution of Mining and Metallurgy, the Institute of Metals, the Iron and Steel Institute, and this Institution.

ENEMY ALIEN MEMBERS.

The Lords of the Privy Council have allowed the additional bye-law passed by the Council and General Meeting, which excludes all enemy alien members from membership of the Institution in the event of a state of war existing between the United Kingdom and any other country or state.

MINING STUDENTS ON SERVICE.

The Committee appointed for the purpose have not ceased in their efforts to obtain certain concessions on behalf of mining students on service with the colours who are desirous of sitting for their Certificates of Competency under the Coal Mines Act on their return from active service, but regret that their efforts have only been partially successful. Certain concessions have been granted with respect to the written and oral examinations, but no alteration has been made in the statutory conditions for practical experience; whilst the certificate granted to candidates who successfully pass the examination will be witheld until the statutory three or five years' practical experience has been gained by them. The Committee have been requested by the Council to continue their efforts on behalf of these students.

LIBRARY.

During the year 19 volumes have been added to the Library, which now contains 2,626 volumes.

PUBLICATIONS.

Three Presidential Addresses and thirty seven papers have been printed in Volumes LIV. and LV. of the *Transactions*. Owing to the restrictions placed on the use of paper, and to the abnormal increase in the charges for printing, the Council have been faced with great difficulties in continuing the publication of the *Transactions*. With a view to economizing paper, they have decided to suspend during the continuation of the war the publication of the printed list of members and the abstracts of foreign and colonial papers. It may, however, be necessary to still further curtail the publication of papers.

The question of the joint publication of abstracts by this Institution and kindred societies is being investigated.

The Council have authorized the preparation of an authors' and subject-matter index to Volumes XLI. to LV. of the *Transactions*, which will be issued to the members as soon as the necessary paper required for printing it is available.

By arrangement with the Director of the Meteorological Office, South Kensington, tables giving the mean declination of each two hours of the day, with means for the day and means for the week, are now published monthly in the *Transactions*.

The Council have decided, under certain conditions, to supply, during the continuation of the war, the *Transactions* free of charge to each member on active service.

An exchange of publications has been entered into between this Institution and the University of California.

Y.M.C.A. CHRISTMAS APPEAL.

In response to an appeal from the National Council of Y.M.C.A.'s for a donation towards their Christmas Fund, the sum of £710 17s. 5d. was subscribed by the members of the Institution and handed over to that Council.

FINANCES.

The invested funds of the Institution remain unaltered, with the exception that the two bonds (£1,000 and £200) for the sum of £1,200 lent to the Tyne Improvement Commission at 3½ and 3¾ per cent. respectively, have now been renewed as one bond for a further period of five years, with interest at 5½ per cent. per annum.

The statement of accounts herewith submitted shows the ordinary income for the year ended July 31st, 1918, to have been £4,674 14s. 9d., as compared with £4,473 14s. 8d. for the previous year. The expenditure amounted to £4,444 1s. 10d., as compared with £3,633 10s. 2d. for the year 1916-1917. The balance of assets over liabilities, exclusive of capital funds and of the value of the stock of *Transactions*, but inclusive of the value of furniture and fixtures (after allowing for depreciation), now stands at £3,869 17s. 9d., as against £3,639 4s. 10d. for the previous year.

THE INSTITUTION OF MINING ENGINEERS: ABSTRACT OF INCOME-AND-EXPENDITURE ACCOUNT FOR THE YEAR ENDED JULY 31ST, 1918.

EXPENDITURE.	£	s.	d.	Year 1916-1917 £	s.	d.
Printing and issuing *Transactions*, excerpts, etc.	1,631	17	3	1,243	4	11
Postages	304	17	5	1,272	19	6
Stationery and incidental expenditure ...	274	4	0	189	9	5
Salaries, indexing, travelling expenses, etc.	1,581	13	11	340	12	5
Office rent, cleaning, lighting, etc.	474	7	0	456	14	11
Cost of meetings	35	6	1	19	18	6
Cost of transfer of investments	0	0	0	19	13	5
	4,302	5	8	3,542	13	1
Surplus	230	12	11	840	4	6
	£4,532	18	7	£4,382	17	7

INCOME.	£	s.	d.	Year 1916-1917. £	s.	d.
Capitation fees	2,989	0	0	2,907	0	0
Sales of *Transactions*, excerpts, etc. ...	464	15	6	463	14	2
Advertisements (*less* commission)	311	1	10	272	11	3
Interest from investments, etc.	593	18	6	568	7	8
Reclaimed income tax	174	2	9	171	4	6
	£4,532	18	7	£4,382	17	7

ABSTRACT OF BALANCE-SHEET, JULY 31ST, 1918.

	£	s.	d.	Year 1916-1917. £	s.	d.
Sundry creditors	537	13	1	730	16	11
Balance of assets over liabilities	18,900	1	4	18,669	8	5
	£19,437	14	5	£19,400	5	4

	£	s.	d.	Year 1916-1917. £	s.	d.
Sundry debtors	310	9	9	418	18	11
Investments at cost	17,030	3	7	17,030	3	7
(actual value of above at July 31st, 1918, £13,314 11s. 8d.)				(actual value of above at July 31st, 1917, £13,377 2s.)		
Interest accrued	289	16	4	263	6	7
Cash at Bank	1,651	17	1	1,495	2	4
Office furniture	155	7	8	192	13	11
	£19,437	14	5	£19,400	5	4

The Annual Report was unanimously adopted.

ELECTION OF OFFICERS, 1918-1919.

The election of officers for the year 1918-1919 was announced as follows:—

President:
Mr. George Blake Walker.

Vice-Presidents:
Mr. W. C. Blackett.
Mr. Frank Coulson.
Mr. C. C. Ellison.
Mr. John Gregory.
Mr. T. Y. Greener.
Mr. James Hamilton.
Mr. C. C. Leach.
Mr. W. D. Lloyd.
Mr. Sam Mavor.
Mr. H. Eustace Mitton.
Mr. D. M. Mowat.
Mr. A. J. A. Orchard.
Mr. William Pickup.
Mr. F. R. Simpson.
Mr. Alexander Smith.
Mr. George Spencer.

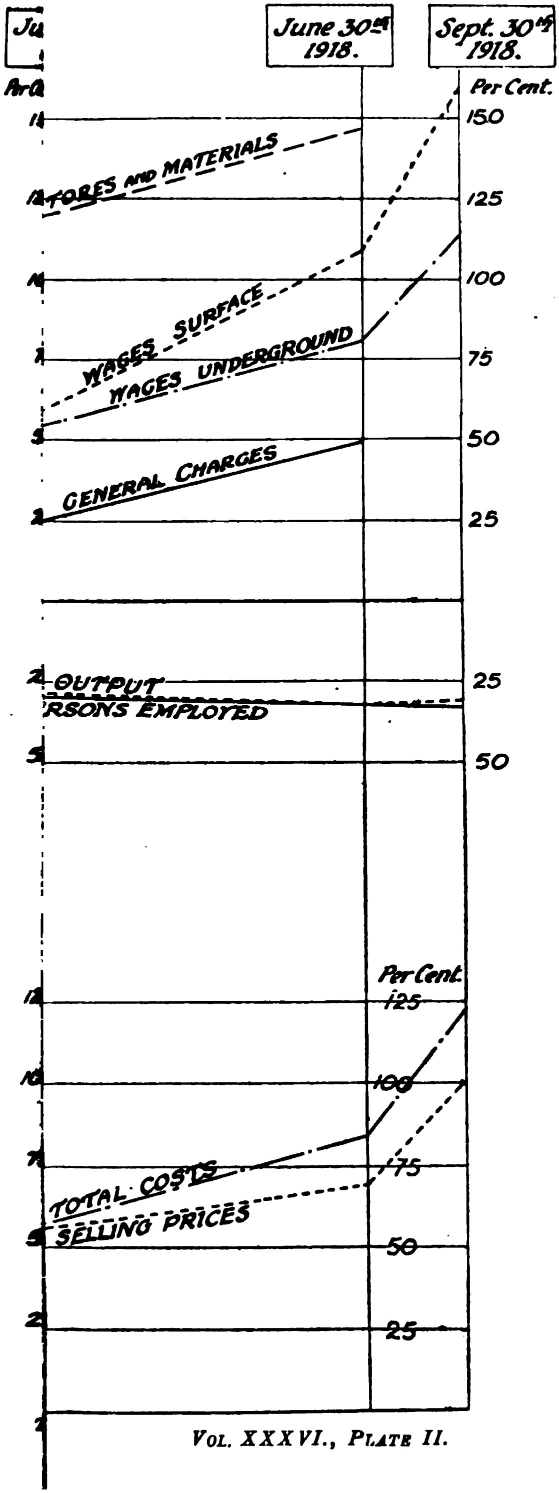
Auditors.

Messrs. John G. Benson & Sons, chartered accountants, Newcastle-upon-Tyne, were re-elected the auditors for the year 1918-1918.

Mr. George Blake Walker then took the Presidential chair, and delivered the following Address:—

VOL. LVI., PLATE II.

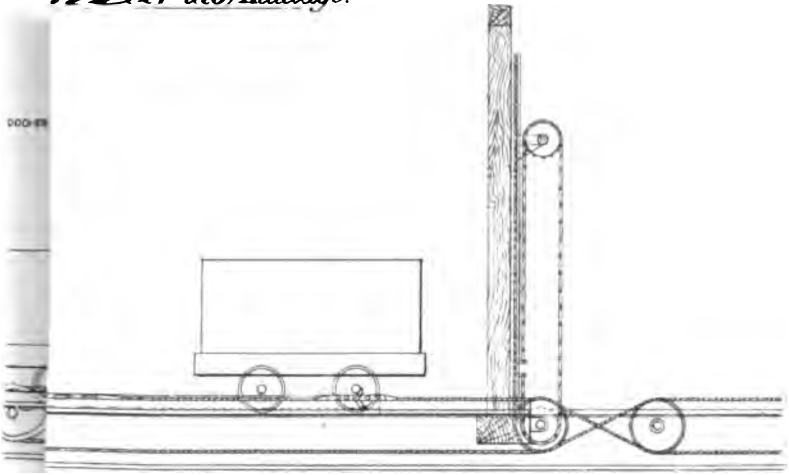
ess.”

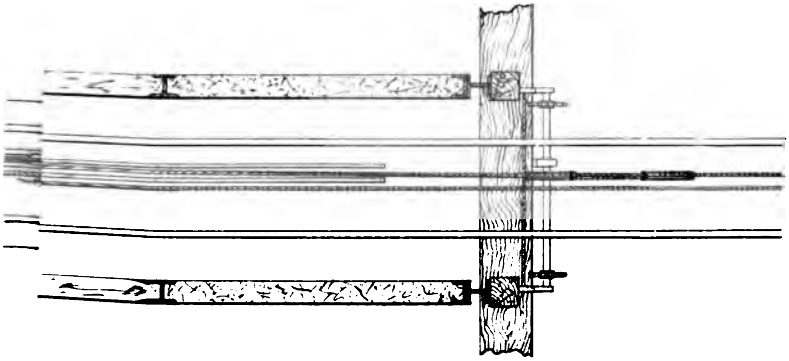


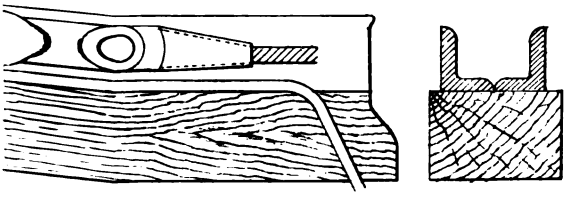
VOL. XXXVI., PLATE II.

The [illegible] Bottom of the Upcast Pit, [illegible]er-tub) Haulage.”

Vol. LVI. Plate III.







The

Vol. XXXVI., Plate III.

PRESIDENTIAL ADDRESS.

BY GEORGE BLAKE WALKER, M. ENG., M.I.C.E.

I have to thank you for the great honour you have done me in electing me as President of the Institution. In following in the steps of so able a President as Mr. Thorneycroft, I feel that I have a task before me which it will be difficult to perform in many respects. I can only promise to do my best, and rely on your kind indulgence.

We have now entered upon the fifth year of this terrible European war. Every section of the community has had to bear its share of the loss, inconvenience, and cost which that war has involved, and the mining industry has had its full share of the heavy toll of life and limb as the result of the conflict. It seems to be admitted by our generals that the men who have gone forth as representatives of the mining community have distinguished themselves by their valour in the field beyond most other classes of citizens, and by their resource and ingenuity in connexion with the difficult problems for which they have had to qualify themselves in a very short space of time. In particular I may refer to the Tunnelling Companies of the Royal Engineers, whose services in connexion with the earlier stages of the war were described by Lord French as being unsurpassed by any other branch of the service. We shall probably hear more when the troops return of the considerable engineering works which the miners have helped to carry out. I am sure if we knew half what our men have accomplished, we should be filled with pride at their achievements. We must never forget that ours is essentially a citizen army; our men had had no previous training for war, and they have had to adapt themselves to fight with a nation who for generations has been carefully preparing for this struggle, and has been equipped with the most diabolical engines of destruction ever devised. We have, therefore, great cause for thankfulness and pride for the part which the mining community have borne in this war, and that hitherto the decision has not gone against us.

But it is not merely in the field itself that the importance of the coal-mining industry has been emphasized. We have had to supply not only our own requirements, and provide fuel for the immensely increased output of munitions and material necessary for the war for our own armies, but have had to supply the allied nations, especially France and Italy, with coal. The French coalfields have been overrun by the Germans, and their plants as far as possible destroyed, and those which have not actually been destroyed have been prevented from producing coal; hence the burden of supplying our allies with the materials for continuing their munition industries, their transport, and their domestic consumption has fallen almost entirely on this country, and has produced a very serious shortage that will make coal scarcer than ever has been the case in the past. This shortage has emphasized the immense importance of our coal industry to ourselves and the world at large. It behoves us, therefore, to look with the greatest care and anxiety on what the outlook for the future really is. The Government have appointed a Committee on Scientific and Industrial Research, and no doubt The Institution of Mining Engineers will be asked to co-operate in the enquiries into several important matters, amongst the most important to my mind being the question of the conditions of mining at great depths.

Everyone is aware that the period through which we have passed during the last half century was the most favourable for the production of abundant and cheap coal. We were working seams which lay within a moderate distance from the surface, and where the conditions of temperature were such that labour could be employed without imposing conditions prejudicial to human effort. But that period is rapidly drawing to a close, and we are now confronted with the problem of coal that will have to be worked at depths where the conditions will make the results of human labour far less effective. Dr. J. S. Haldane has devoted special attention to the conditions under which it is possible for human beings to do laborious work where high temperatures prevail. As we go deeper into the crust of the earth, it is well known that a progressive increase in rock temperature occurs with increasing depths. There seems to be a good deal of variation in the rate of increase. At the Dolcoath Mine, Cornwall, it is about 1° Fahr. for every 60 feet, whereas in the deep mines near Birmingham the rate of increase is only about 1 degree in about 110 feet, and in the Transvaal the increase is a great deal less, namely, about 1 degree in 220 feet. But it is not only the rock temperature which has to be contended with. In our deep coal-mines a very considerable increase of temperature is due to the oxidation from the strata which are being worked, and unless there is a very powerful ventilation the heat given off by oxidation may be greater than that due to the temperature of the rock itself. There is also the less important source of heat from compression, which warms the air about 5½° Fahr. for every 1,000 feet of depth. Dr. Haldane writes that—

"The living human body is a marvellously efficient thermostat; but there are limits to what it can do without artificial aid. Some years ago, when I was investigating the ventilation of Cornish mines, I determined on myself its limits in the upper direction. . . . My experiments showed that in still air and during bodily rest the body temperature began to rise as soon as the wet-bulb temperature exceeded 88° F. It did not matter in itself what the actual temperature of the air was, or what its dew-point or absolute percentage of moisture, or relative humidity were. Air at 150° produced just the same effect on body temperature as air at 88° if in each case the wet-bulb temperature was 88°. . . . It is only when one is at rest that one can keep the body temperature normal in still air at 88°. During muscular exertion a considerably lower wet-bulb temperature is needed. Of course clothing is also of much importance. At wet-bulb temperatures over 80° a man cannot do much continuous work in still air, even with nearly all clothing removed. . . . When the body temperature begins to rise owing to a high wet-bulb temperature, it does not stop rising, so far as I am aware, till death occurs, or till removal to cooler surroundings."*

It may be said generally that the wet-bulb temperature of the air in the working-places of a mine must not exceed 82° Fahr. in order to support the conditions of human life, and we are rapidly approaching that temperature in many of our mines. There are cases in the neighbourhood of Doncaster and in Lancashire where these temperatures actually prevail. Sir John Cadman, in a paper he read before the North Staffordshire Institute of Mining and Mechanical Engineers,† cites a number of instances in which this temperature is reached. He cites a case (No. 25, page 517) where the dry-bulb temperature was 111° and the wet-bulb 82° Fahr. He makes the following remark:—

> "Large current of air passing here; men were working naked, pushing wagons about. The writer did not feel any great inconvenience, perspired freely, and moisture evaporated from the body very quickly; quite comfortable at rest; eyes felt a little burning sensation. Rails and wagons felt hot to the touch."

Obviously, despite a good ventilation not much useful work could be done under such conditions. According to Dr. Haldane, the body temperature of the human being must not rise above 102° Fahr. or fatal results will probably occur. Even with the wet-bulb temperature at 78° Fahr., the body temperature can hardly be prevented from rising during moderate work in still air. In a good air-current, on the other hand, continuous moderate work was possible with the wet-bulb at 85° Fahr. The relief afforded by evaporation through perspiration is the all-important safeguard; but there are, of course, practical limits, and although a higher temperature may be sustained for a short time, 100° Fahr. dry-bulb may be taken as the limit for practical purposes of the temperature at which men can work, and at such temperature efficiency would be greatly reduced.

From figures which have been furnished to me, I find that at a depth of 1,950 feet the dry-bulb temperature in the working-places of one of the newest and best equipped collieries in South

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* *Trans. South-Eastern Union of Scientific Societies*, 1917, pages 71-73.

† *Trans. Inst. M. E.*, 1912-1913, vol. xlv., page 509.

Yorkshire, with an ample ventilating current, was generally 74° Fahr. At a depth of 2,220 feet, at another colliery near Doncaster, the temperature in the working-places was generally 80° Fahr. In a third case in the same neighbourhood, at a depth of 2,730 feet, the temperature was with difficulty kept down to 87° Fahr. I am informed that at the last of these collieries many of the men suffer from boils and anæmia, and their working efficiency is reduced by 20 per cent. Can these conditions be mitigated on a practical scale so as to make physical exertion healthy and efficient?

It may be assumed that the temperature of the air at the bottom of a downcast shaft 3,000 feet deep is 6 to 7 degrees higher than at the surface in cases where a large volume of air is passing. If the surface temperature is 50° Fahr., the air will enter the mine at, say, 57°; but in hot weather the rise in the temperature of the air at the pit-bottom will not be as much as 6 or 7 degrees. In a case which came under my own observation—the Sydney Harbour Colliery in Australia, where the summer temperature was 80° Fahr. and upwards on the surface—the temperature at the pit-bottom (depth, about 2,500 feet) was sometimes a degree or two less than at the surface, and in the workings (1,500 yards in-bye) the temperature was only 86°—not very much more than the surface temperature.

It is of great importance that the oxygen of the air carried into the mine for ventilation should act as little as possible on the strata; and airways which have a smooth surface cause less friction and resistance to the ventilating current than those which are less smooth. Cement linings of airways have been used largely in the mines of Courrières and other French collieries, and are said to have been quite economical. The airways are roughly reduced to a circular or oval form, and are coated with a thin shell of cement a few inches thick. This cement gives some support to the roadway, but its principal value is in preventing the air from leaking into the goaves or the roof, and the heat from passing from these and raising the temperature of the intake air. A description of this system has just been published by the United States Bureau of Mines, and an abstract has been circulated to the members of two of the local Institutes under the title of the " Cement Gun."

In the Doncaster district, a seam underlying the Barnsley Bed (the Dunsil) is being utilized for the purpose of constructing intake or return airways independent of the main seam. By this means the separate ventilation of districts and panels of workings is being carried out in such a way that the temperature prevailing in any panel or district can be kept down to the minimum, and the best conditions for the workmen secured. This system seems to lend itself to the introduction of cooling (or refrigerating) apparatus, which may at some future time be considered worth introducing. From what I have been able to ascertain, a large volume of air could be reduced in temperature by 10 degrees, with a comparatively small expenditure of power. If, therefore, such a system as the employment of a subsidiary seam were adopted, and communications were made between the subsidiary and the main seam at any required number of points, a supply of cooled air could be carried to these various points of communication between the seams, and the general temperature of the mine thereby reduced to a reasonable degree. It is in some such direction as this that the solution of this difficult problem may be found. It would be presumptious on my part to offer any suggestions to the eminent engineers who are already dealing with this matter, but it is only right to mention what is being done.

If we have already reached a point at which human energy becomes less effective, and the working of coal is to be continued under such conditions, muscular effort will have to be supplanted by mechanical appliances. Already a great deal of machinery is employed in the working of coal where in days gone by the miner's pick was the only implement. Coal-cutting machines have for many years been in use, but it has generally been for other reasons than those of high temperature. It has been. hitherto mainly in the thinner seams that these appliances have been called in, and their use has not appeared to be economical in seams thicker than 4 feet, but when they have to be used mainly on account of the excessive temperature of a mine, they will no doubt be applied to the thicker seams. The same machines as are employed in thin seams will, of course, not be as a rule suitable, and special devices will have to be designed in order to meet the new conditions. In Canada and America percussive picks are largely used in seams of 8 feet thick and over, and probably something of the kind will be made use of here. Explosives will probably not be required, as at great depths the coal comes down very easily. The use of ponies in the mines has been reduced a great deal in recent years, and small mechanical haulage appliances have been substituted. This will be necessary in an increasing degree in very deep mines. The ponies suffer very much from the heat, and the manager of one of the deep mines near Doncaster told me they had taken out all their ponies for this reason, and small haulages and conveyors have taken their place. For these mechanical appliances compressed air will be required, or it may be a combination of compressed air and electricity. To carry compressed air great distances underground is most expensive, and perhaps it may be found permissible to have air-compressing plants distributed throughout the workings and supplied with electric power.

In order to reach coal at a depth of 3,000 feet and over, very large expenditure on sinking shafts must be incurred. Shafts are now made very large, 20 feet in diameter and upwards, and a pair of such shafts may cost as much as £60,000, irrespective of the equipment. To justify such expenditure, areas up to 5,000 acres are designed to be worked to a pair of pits, but the difficulties of temperature will limit the distances to which the workings can be extended. Shafts will have to be more numerous, so for private enterprise such expenditure may be prohibitive; but if the collieries become the property of the State, the element of cost becomes one of secondary importance. So long as private capital is employed in coal-mines, the question of the return on it must decide what expenditure can be incurred; but the State will not be concerned primarily with the question of profit, and the expenditure will only be limited by the rate at which the money expended on winning and working the coal can be borrowed. The price of the coal will be eventually the amount necessary to pay the interest, and here we have, of course, to remind ourselves that there is a limit beyond which it will not be worth while to produce coal. The cost of production must not exceed what the general trade of the country can bear. The collieries exist for the benefit of the country, not the country for the collieries. Often a good deal of the capital put into colliery enterprise is lost. Companies are wound up or reconstructed, and the new-comers acquire the property for a fraction of what has been spent on it. That will not be the case with State mines: the country will be responsible for every pound expended, and the interest will have to be provided regularly by Parliament. The general trade of the country, and more particularly the export trade, must be done at competitive prices. We have to meet the competition of the whole world. It can hardly be questioned that the chief material basis of the great industrial and commercial expansion of this country during the past century has been its abundant supplies of easily obtainable coal, which, until recent years, has given us a position of advantage over all other countries. It is also equally true that we can no longer claim any advantage in this respect over our two closest competitors.

The International Geological Congress, Canada, held in 1913 issued a report on the world's coal resources, according to which the geographical distribution of the world's possible and probable reserves of coal of all kinds available within 6,000 feet of the surface, amounting in all to 7,397, 550 million tons, should make us realize that large as the quantity of coal is it is not limitless. The fact that the available reserves of coal in Great Britain amount to only about a fortieth, whilst those of the whole Empire do not amount to more than a fourth of the world's estimated total, is one which ought to be brought home to everyone responsible for the economical development of our national and imperial resources, especially in view of the fact that the United States, whose competition in the immediate future will probably be more severely felt than ever before, possesses more than half the estimated world's store of coal. This estimate of 7,397,550 million tons is based on the possibility of following the coal to a depth of 6,000 feet from the surface.

The British Royal Commission on Coal Supplies adopted a depth of 4,000 feet as the limit at which coal-mining could be advantageously prosecuted. I venture, however, to suggest that these depths are altogether fallacious, and that the available quanities of coal are largely overstated. The quantity estimated by the Royal Commission on Coal Supplies in their report was 39,483,000,000 tons. If this quantity be reduced by 20 per cent., it leaves 31,586,400,000 tons. The quantity of coal produced in this country during the quinquennial period 1910-1914 was 270,000,000 tons per annum, and if we adopt the reduced quantity our coal will be exhausted at this rate in 116 years.

As the conditions of temperature in the pits in the neighbourhood of Doncaster (which have not actually reached 3,000 feet) already make human labour ineffective, it seems to be useless to estimate what coal there may be between 3,000 and 4,000 feet, and to count upon it as if it were actually workable, much less at the greater depths of 5,000 and 6,000 feet which have been confidently spoken of as within the limits of practicability.

As lately as the seventeenth century coal-miners had only the status of serfs, and were attached to the mines, which they were not allowed to leave; their hours were long, the conditions of their service were very bad, and the payment they received very niggardly; but in the times in which we are living these conditions have been completely reversed: the coal-miner is now the best paid member of the community, and there seems to be no limit to the wages which they may demand in the future. Mr. Smillie at the Southport Trades Union Conference declared that if the miners claimed £2 or £2 10s. per day, they would not from the point of view of their importance to the nation be claiming too much. It is not, however, only in the direction of wages that extraordinary claims have been made: it has been suggested that the working days should be limited to 5 per week and the working hours to 6 per day, payment to be made as for 6 days and 8 hours per day as at present. Possibly it may be in view of the more arduous conditions to which I have already referred that these shortened periods of work are demanded; but the miner is not superior to economic law, and he will not be able to extract from the coal industry more than the coal industry will produce.

We have had "boom" times before, when wages have risen to a very high level, but they have been succeeded by times when wages fell to a very low point. We are told that the collieries will not revert to their old owners after the war. That remains to be seen, but whoever works the collieries must obtain for the coal at least what it costs. The cost of coal has doubled during the last six years, and so has the price to the public. If, therefore, the high rates of pay continue after the war, the price to the public will have to remain at its present very high figure, and the cost of manufactured articles will also remain very high in price. How this country with this serious handicap is going to compete for its share of the trade of the world is at present a conundrum. It is an important part of the problem on which the future of the country depends. If we cannot keep our trade because our coal is too dear, it will cease to be in demand: the price will fall, and as the price falls, wages will follow. Doubtless the collier will always be one of the best paid men in the country, but his wage will be limited to what the country can afford to pay him. In some ways I welcome the State ownership of mines: it will then be possible to get at the facts of the cost of production. To-day the miners' leaders seem to question the necessity of raising the price of coal in order to meet advances in wages. The Controller is worried as to how he is to make ends meet. Some experience of State ownership will open many eyes as to the actual profits of collieries, and there is probably a great surprise in store for those who think the average colliery makes a lot of "plunder."

There has been a great deal said during this war-time about restriction of output. The output of colliers has decreased at the present time to about half what it was twenty years ago. You can most of you refer to old books from which you will be able to verify this. If the colliers would work as hard as their grandfathers worked, they could earn double their present wages. At the present day wages are so high that miners do not care to earn all they might earn. Some are satisfied with the "minimum wage"—the most pernicious piece of industrial legislation ever inflicted on the country. In the future if the country is to survive, it must produce its coal cheaply; and if miners are to enjoy high wages, they must be earned consistently with this condition.

I am afraid these observations on the outlook are the reverse of cheerful, but there is no doubt that there is much in the future to cause anxiety to every thoughtful man. The organization of society is in the melting-pot, and power is passing more and more into the hands of men who are lacking in experience, and rather rejoice in the fact—whose idea is rather to pull down and destroy than to build and re-construct; and, as we have seen in Russia, the elements of discontent and jealousy have immense powers for destruction. This country has reached a magnificent position of prosperity and wealth. We can only hope that the sturdy common sense of the British people will keep them from wrecking the edifice which our forefathers have reared stone by stone throughout the centuries.

A hearty vote of thanks was accorded to Mr. Wallace Thorneycroft for his able and active services as President during the past year.

PRESENTATION OF THE INSTITUTION MEDAL.

The **President** (Mr. G. Blake Walker), in making the presentation, said: It is a special personal pleasure that it should have fallen to me to present the Institution Medal to my old friend Mr. Charles Edward Rhodes, for being a near neighbour I have had the privilege of watching his carrer for some forty years. Mr. Rhodes has been in a special sense the embodiment of mining engineering in South Yorkshire. He has been identified with the various developments and progress in mining methods both from the point of view of safety and of profitable working, and has always been ready to impart the fruit of his experience and knowledge to those who (like myself) were desirous of profiting by it. Many of us, Mr. Rhodes, owe you a deep debt of gratitude.

A native of Rotherham, you commenced your mining life in 1867 with the well-known firm of J. and P. Higson, of Manchester, and were at Wombwell Main Colliery and other collieries in South Yorkshire, and also in Lancashire, where there was an opportunity of observing a rapid development in mining work.

You also had the unfortunate experience of assisting at many serious explosions both in Yorkshire and in Lancashire. The experience gained there, when naked lights were almost universal and gunpowder was the only explosive used, brought you rapidly to the conclusion that these were the two primary factors in connexion with explosions, and that the introduction of safety-lamps, with some other means of blasting than that of gunpowder, would have to be resorted to.

On taking up in 1873 the position of manager under Messrs. John Brown & Company, Limited, at their collieries at Rotherham, you recommended that safety-lamps should be introduced in lieu of naked lights, which were then common throughout the district, with the exception of one or two collieries such as the Oaks, Lundhill, and Wombwell Main, near Barnsley. The directors at once acceded to the request, but unfortunately before the lamps could be obtained a small explosion took place.

The introduction of lamps rapidly followed throughout the district, but occasional explosions still took place, and it was felt, after some experiments on a small scale had been made, that the then safety-lamp was not a satisfactory one.

You conducted a large number of experiments in conjunction with a Committee appointed by the Midland Institute, the late Mr. Smethurst of Wigan being one of the pioneers in investigating the question of lamps. You assisted in their investigations a Committee which was set up by the Government under the presidency of the late Sir Warington Smyth, the result being a very considerable improvement in safety-lamps generally.

Explosions, however, still occurred, and the question of improved explosives, or some other means of getting down the coal, was the subject of the investigation. You assisted at experiments with lime cartridges, various types of wedges, and other appliances for getting down coal, and read papers before the Midland Institute.

You conducted experiments on a small scale at Aldwarke Main Colliery, as coal-dust then began to be discussed as a probably serious source of danger, and these demonstrated beyond doubt that an infinitesimal portion of gas, coupled with dust, would cause a violent explosion; but as the appliances used were of a limited size, it was not possible at that time to get a pure dust explosion. The danger of dust, however, had been fully demonstrated in various parts of the country, and the matter was taken up by Sir William Garforth, the result of whose experiments are well known to the whole of the mining world.

You also made numerous experiments as to the safety and efficiency of high explosives, a subject which came to the fore. This matter was taken up by other bodies, and resulted in much improved conditions all round in connexion with safety.

You endeavoured to introduce electric safety-lamps many years ago, but could not then obtain a satisfactory battery. As time went on, several improvements were effected, and the offer of a prize by the late Sir Arthur Markham culminated in a large number of lamps being bought together for competition, so that an electric safety-lamp of a very satisfactory character is now an accomplished fact, and is largely used in mines.

You have sunk shafts in Yorkshire to all depths down to 800 yards, and under various conditions; you have had the advantage of being able to develop very large areas of coal in the district, and are associated with the principal undertakings. You have been connected with mining for over 50 years, and the developments during that period are hardly appreciated by those who have not had an opportunity of seeing the result of continuously growing experience.

Mr. C. E. Rhodes (Rotherham), in accepting the medal, said: There is no testimonial of esteem which would commend itself as much to me as the presentation which has just been made to me on your behalf by your President. The poet has said: " The past is as yesterday "; but, after all, when one looks back over fifty years what happened in the extreme fringe of that past is ever present in mind. The conditions existing at the present time, however, are so absolutely different from what prevailed long ago that the youngest generation can hardly appreciate the vast improvement which has been effected in the management of collieries and the various methods adopted not only for economical but for safe working. It has always been the object of every mining engineer and manager to get coal with a minimum amount of risk and a maximum amount of safety to those who produced it. The work of this and other Institutions has resulted in the embodiment in a code of legislative provisions that have for their primary object the safety of those employed underground, and without the efforts of these various Institutions and the individual efforts of members of our profession like the late Sir Warington Smyth, Sir William Garforth, and others, we should not now be working our mines with anything like the scale of safety at which we have arrived, and which I hope may continue to improve. If in my small way I have been able to do anything in this direction, I am more than repaid by the feeling that I have been associated with men who have brought the primary industry of this country—the one on which its whole prosperity depends—to the success which it has attained at the present time. I do not think that anyone outside the profession can appreciate the difficulties which have had to be confronted in connexion with the carrying on of collieries during the past four or five years. The strain of the war, the difficulty of dealing with labour, and the obligations imposed upon us by the Control Board—manifestly for the benefit of the community—have caused great discomfort and anxiety to those responsible for the carrying on of this huge industry. Nevertheless, we have every reason to congratulate ourselves that, despite the extreme depletion of labour, we have been able to keep our collieries going and producing the outputs they are doing, and that we have successfully coped with conditions which no one anticipated we should ever be called upon to deal with five or six years ago. I can only say that there is nothing in the world which could give me greater pleasure than I have experienced in receiving this testimonial of—I hope I may say—your regard. I have to thank you, Mr. Blake Walker, for presenting it, and my fellow members for having been good enough to give me this token of their goodwill.

A METHOD OF DETERMINING THE MAGNETIC MERIDIAN AS A BASIS FOR MINING SURVEYS.

BY T. LINDSAY GALLOWAY, M.A., F.R.S.E.

In surface surveying, and in the setting-out of works aboveground, the most convenient line of reference is undoubtedly the true north or geographical meridian. This is the line to which all national standard maps and plans are referred, and, when not already known, its direction can always be ascertained with great accuracy and comparative ease by astronomical methods. It was a bold conception of Mr. Beanlands to extend the use of astronomical methods to underground surveying. Even in cases where there was no access by adit-level or inclined shaft, he proposed to determine the true north line by observing the transits of stars from the bottom of a vertical shaft.* But this idea was difficult to carry out in practice, and Mr. Beanlands found it more practicable to place his transit instrument at the top instead of at the bottom of the shaft; and by looking downwards, and fixing with great accuracy the position of two marks at the bottom of the shaft, he was able to determine a line which could be afterwards extended so as to form the basis of a survey. Notwithstanding some very successful results obtained by this method, it is obvious that the risk of error is considerable, and a small inaccuracy may give rise to serious consequences by reason of the shortness of the base-line.

An improvement upon Mr. Beanlands' method was successfully employed by Mr. Richardson in setting out the line of the Severn Tunnel, the principle of which was that, instead of fixing marks at each side of the shaft, a long wire was stretched horizontally across the bottom, and its direction fixed by observation with a transit instrument placed at the top. By this means a longer base was obtained.†

Compared with the transit instrument, it must be admitted that the ordinary magnetic needle as fitted to mining compasses is a very inadequate appliance for fixing and setting out lines; but its great convenience, its moderate accuracy, and the circumstance that it can be set up almost anywhere and its indications checked as often as desired, are good reasons why it still remains the most usual means of fixing directions underground. Its defects and limitations are obvious. As ordinarily constructed, its indications can only be read to the nearest degree, the smaller subdivisions being estimated by the eye. Its mode of suspension also is far from perfect, for a jewelled cap resting upon a steel pivot, however finely made, cannot be totally devoid of friction.

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* "On Mining Surveys," by Arthur Beanlands, *Trans. N. E. Inst.*, 1855-1856, vol. iv., page 267; and "On Recent Improvements in Underground Surveying," by Arthur Beanlands, *ibid.*, 1870-1871, vol. xx., page 85.

† *Engineering*, 1882, vol. xxxiii., page 48.

It has been my aim for some time past to devise a simple magnetometer, and a method of determining the magnetic meridian from it, with the aid of the theodolite, so as to secure the inestimable advantages of the telescope and vernier. This is the more desirable as accurate records of the variations of the magnetic declination are now published in our *Transactions* and elsewhere, and a good deal of attention has been drawn to the subject by a recent Presidential Address and by Dr. Chree's admirable and comprehensive paper.*

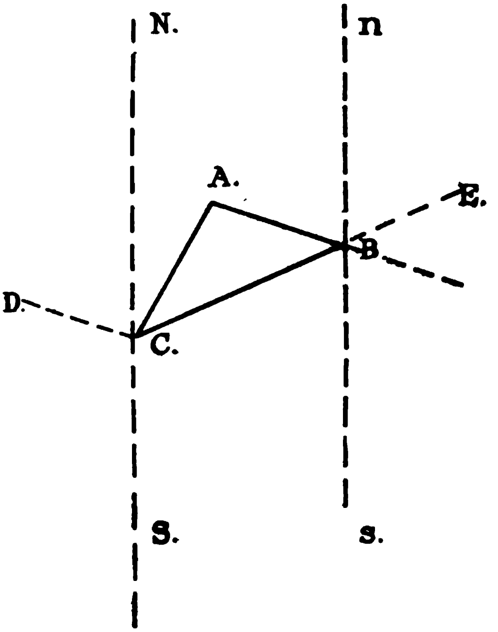

FIG. 1.—DIAGRAM SHEWING POSITIONS OF TRIPODS. DC BEING PARALLEL TO A B, D C B IS EQUAL TO ABE. THEREFORE NCB, WHICH IS THE HALF OF DCB, IS EQUAL TO nBE, WHICH IS THE HALF OF ABE. THEREFORE NC IS PARALLEL TO nB.

In the method about to be described, the only instruments required are a theodolite, three tripods, and a simple appliance, which may be called a "magnetic reflector." The latter, which will be described more in detail afterwards, consists essentially of a small plate-glass mirror, to which is cemented a flat magnetized bar, the whole being delicately suspended by a single fibre of unspun silk, in the manner frequently employed in physical laboratories and observatories. The procedure for finding the magnetic meridian is as follows:—Place the magnetic reflector on one of the tripods, adjust it by the levelling-screws, set free the the mirror, and allow it to swing until it comes to rest in the plane

* *Trans. Inst. M. E.*, 1917-1918, vol. lv., page 223.

of the meridian. Place the other two tripods, each having a plumb-line suspended from its centre, at convenient distances in front of the reflector — not *directly* in front, however, but somewhat to each side, and far enough apart to admit of distinct focussing when a sight is taken from one to the other. Place the theodolite on either of the tripods and cause the other to be moved, if necessary, until the image of its plumb-line can be seen reflected in the mirror. The following observations are now to be made, and at each observation the cross-wires in the telescope must be brought into exact coincidence with the image of the plumb-line, whether viewed direct or reflected, as the case may be.

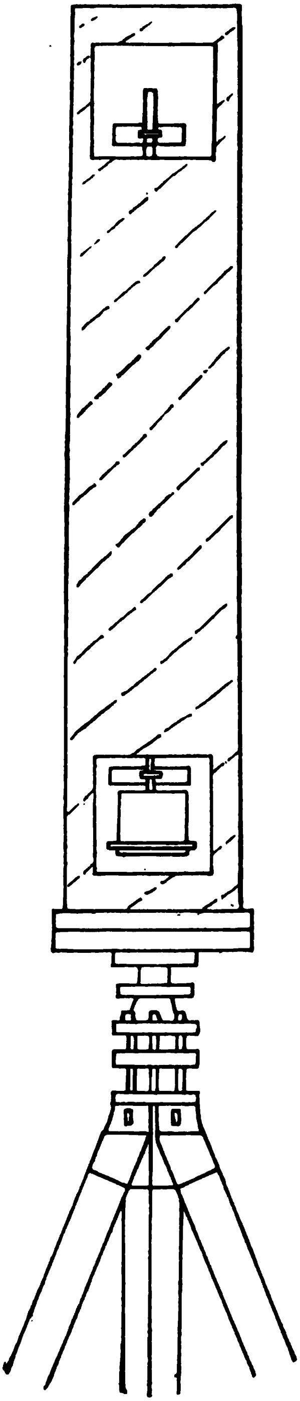

Fig. 2.—Front View of Magnetic Reflector.

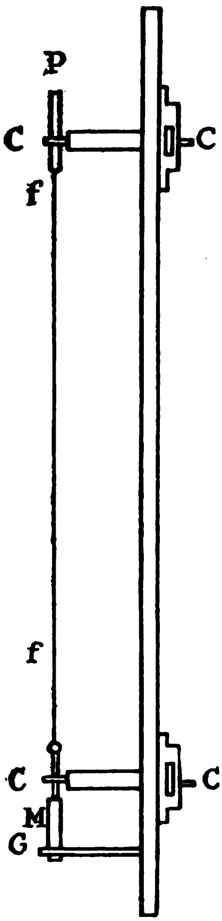

Fig. 3.—Side View of Back, showing the Suspension. *P* is the Counterpoise, *CC*, *CC* the Supporting Clamps, *ff* the Fibre, *M* the Mirror, and *G* the Guard.

Referring to Fig. 1, *A*, *B*, *C* represent the tripods, *B* being the one which carries the reflector. Place the theodolite at *A*, turn the zero towards *B*, clamp the axis, and turn the instrument through the angle *BAC*; clamp the vernier, unclamp the axis, and remove to *C*; turn the instrument towards *A*. The zero will now lie in the direction *CD*, parallel but opposite to the original direction *AB*.

Clamp the axis, unclamp the vernier, and turn the instrument towards *B*. The angle now recorded on the horizontal circle is to be noted. It is evidently the angle DCB. If the instrument be turned back through half this angle, the centre-line of the telescope will be parallel to the face of the mirror, and therefore in the plane of the magnetic meridian The graduation of the theodolite has been assumed to be in clockwise direction. If otherwise, the order of procedure is to be reversed. The process, it will be seen, is extremely simple and geometrically exact. Having determined the magnetic meridian, the surveyor may proceed with the remainder of the survey in the usual manner, and can check the meridian-line at any other suitable point by repeating the same process.

It is evident that the magnetic reflector (Figs. 2 and 3) should be as simple in construction as is consistent with accuracy. It would not be practicable to use elaborate or delicate instruments under the conditions ordinarily to be met with in mines. Keeping this circumstance in view, I have endeavoured to design an appliance which is quite simple and portable. Externally it consists of an oblong box having plate-glass windows in front. The back is removable and carries the suspension and its supports. The mirror, with its little flat-bar magnet cemented to the face, is attached, as already stated, to one end of a single fibre of unspun silk. To the other end of the fibre is attached a small counterpoise of exactly the same weight as the mirror and magnet. Both mirror and counterpoise, when not in use, are held fast by clamps which can be operated from behind, so that, when the box is closed, either the mirror or the counterpoise can be set free, as desired, without opening the box. The object of the counterpoise is to enable all twist to be taken out of the fibre by the very ingenious method employed by Prof. Tanakadate of Tokio.* For this purpose the box is first set up with the mirror uppermost and the counterpoise below. The counterpoise is unclamped and allowed to turn about freely until it comes to rest. One may then be certain that there is no twist remaining in the fibre. The counterpoise is clamped, and the box inverted, with the mirror downwards. It is now ready for use. But one must make sure that the fibre does not again become twisted. A slight accident, when the mirror is set free, might cause it to spin round through one or more revolutions. Not only must such an accident be prevented, but one must be certain that when the mirror comes to rest its position relatively to the counterpoise will remain practically the same as it was when the latter was hanging free. Around the lower edge of the mirror, therefore, is placed a guard, which prevents it from turning through more than a fraction of a revolution. Accordingly, when the box has been set up and the mirror unclamped, it will generally be found necessary, after levelling, to turn the box about its vertical axis until the mirror is seen to be swinging free within the limits allowed by the guard. It will then oscillate under the influence of the earth's magnetism until it comes to rest with the magnet exactly in the plane of the meridian. If the axis of the magnet is not perfectly parallel to the face of the mirror, the latter will deviate slightly from the actual direction of the meridian by a small constant difference. The amount of this can be ascertained either by comparison with a standard instrument, or by direct experiment. But generally such comparison or experiment would not be necessary. For what the surveyor requires is not the absolute direction of the magnetic meridian, but the relative directions of two lines, one aboveground and one underground, or one in one part of a mine and another in another part. So long, therefore, as he uses the same reflector on each occasion, it is immaterial whether it agrees exactly with a standard instrument, or differs from it by a small constant amount.

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* *A Magnetic Survey of Japan,* by Messrs. Knott and Tanakadate.

Certain difficulties and objections to the use of the magnetic meridian as a basis for mining surveys remain to be considered, which I have no desire to ignore or minimize. First of all, there is the influence of local attraction due to the presence of iron. This is a difficulty which can only be overcome by removing all iron from the immediate vicinity of the reflector, or by setting up the latter only where no iron exists. As regards the chance of error arising from the unseen presence of iron, this can be eliminated to a large extent by making two or more determinations of the meridian in different places, and comparing them together.

A further difficulty arises from the fact that the magnetic meridian is itself never, strictly speaking, a fixed line. Its direction is continually changing at all hours of the day and night. These fluctuations are not usually large enough to obtrude themselves on one's notice in using the ordinary compass-needle, and do not seriously interfere with compass surveying. But they become quite apparent in using the method herein described, and as the diurnal variation may amount to 5′ or 10′ or more, its amount is too large to be overlooked in very accurate work. There are circumstances, however, which make this difficulty less formidable than would appear at first sight. Observations made in the evening or early morning do not deviate so much from the daily average as those made within a few hours of noon. The diurnal variation also follows a fairly regular law, so that, in this respect, one day is not unlike another. Thus two observations made on different days at the same hour would generally be in close agreement, particularly if the mid-day hours are avoided.

With regard to the irregular disturbances caused by magnetic storms, these cannot be foreseen or provided against; but, as all movements take place simultaneously, affecting all instruments alike, wherever situated, it will always be possible, by referring to the published records, to find out the variation on any particular day at any given hour. Allowance can thus be made, if necessary, for any unusual disturbance that may have occurred at the time of an observation. A point worth noting in this connexion is that, as the instruments can be set up almost anywhere, it is easy for the surveyor to continue his observations as long as he wishes, or to repeat them as often as he thinks necessary, in order to secure reliable results, without in any way interfering with the other operations at the mine.

Mr. Galloway gave a practical demonstration of his method during the reading of his paper.

The **President** (Mr. G. Blake Walker): We are much indebted to Mr. Galloway for bringing forward an appliance that may reduce materially the liability to errors with which all mining surveyors are familiar. The difficulty of obtaining an extended base-line from which to start underground surveys which exactly determine the position of the surface with regard to the workings, involving the preservation of buildings, etc., has always been present, and any appliance which will tend to make surveys more exact is of great value.

Dr. **Charles Chree**, F.R.S. (London): I am pleased to see that Mr. Galloway has adopted a suspended magnet, which is a great improvement on the ordinary pivoted magnet. A device for getting rid of torsion in the suspension is a valuable auxiliary for high accuracy. "Mirror magnets," as they are called, have long been in use for measuring *changes* of declination, for which they are well adapted, as great sensitiveness can be readily obtained. Without actual experience, I should hesitate to express an opinion on the general convenience of the apparatus and methods. Instruments generally appear complicated until one has some experience of them. Referring to magnetic fluctuations, Mr. Galloway spoke of a diurnal variation of "5′ or 10′ or more." The regular diurnal variation in England has a range of about 5′ in midwinter and 10′ in summer in the average year. But in some years it has been considerably greater than others. Also unless one takes a mean from observations made at the same hour in a number of days, one is concerned rather with the absolute range, or difference between the extreme easterly and westerly positions of the needle, whenever these happen to occur. Taking a mean from 11 years, the average absolute daily range at Kew varied from nearly 10′ in December to fully 15′ in March. As regards magnetic storms, to which Mr. Galloway also refers, I think it is probably best to scrap observations taken on such days. Intercomparisons of Kew and Eskdalemuir magnetic curves on highly-disturbed days have shown large differences. I do not think that at present the knowledge exists which is necessary for applying corrections to observations taken on highly-disturbed days at a distance from a magnetic observatory.

Mr. GEORGE SPENCER (Mapperley Collieries): We are all agreed as to the importance of correct plans, not only for the preservation of important buildings on the surface, but also for the conservation of coal, because in inaccurate or doubtful plans a margin has to be left, and sometimes a considerable quantity of coal which would otherwise be available has to be left unworked. The apparatus shown and demonstrated by Mr. Galloway is most interesting, but it strikes me as being more suitable for permanent observation than for general work in a mine. It is a kind, however, which I have been seeking for a long time in order to obtain the declination at our particular collieries. A very simple and inexpensive apparatus may be provided and fitted up at every colliery; the three points demonstrated by Mr. Galloway may easily be set up, and the declination at any moment ascertained with a tolerable degree of accuracy. There is no provision, however, for reversing the magnet, so that in case the magnetic axis should not coincide with the optical axis, the difference cannot be ascertained except by means of a separate instrument. What is wanted is a simple apparatus that can be manipulated with ease by the surveyors or their assistants whereby the declination at any moment may be ascertained with a fair, or even great, degree of accuracy. As the magnetic meridian varies, not only from day to day, but from hour to hour, there ought in any important survey to be someone on the surface to observe and record the declination at agreed intervals while the survey down the pit is being made, by which means the actual variation of the declination can be ascertained and the proper corrections made. The best time for making a survey is a most important point, and Dr. Chree's observations on that question were most interesting. I had an idea that as the variation was at its minimum about 6 p.m., such hour was the best time for commencing an important survey; but we should all be glad to have further information on that point from Dr. Chree. As to the fixing of an azimuth line, Mr. Galloway has referred to Mr. Beanland's method, and it seems to me to be a very important one. An azimuth line with reference to the true north should be set out on every mining estate, and from that the declination could be ascertained at any time by Mr. Galloway's method.

Mr. R. W. **Dron** (Glasgow): While it is obvious that with sufficient skill and care an accurate meridian may be laid down on the surface, it is very questionable whether the use of the method with ordinary underground conditions will give accurate results. Where the underground surveys are based on the magnetic meridian, a permanent station should be established at the surface at a point free from local attraction and within view of several clearly-defined landmarks. If the magnetic bearings to these marks are taken each time an underground survey is made, any variations can be noted and the necessary corrections made in the meridian used for plotting the surveys. A 6-inch miner's dial fitted with a vernier can be read to the nearest minute, and it is not necessary to estimate the subdivisions of a degree with the eye. Provided due care is taken to allow for magnetic variations, the miner's dial is a most useful instrument for the routine work of a colliery. The main stations underground should, of course, be established by theodolite surveys. If base-lines are to be established by means of a transit theodolite from the top of the shaft, the work must be done by experienced men using expensive instruments. These are not readily available at most collieries, and it would be most helpful if the Ordnance Survey Department would undertake work of this kind. With regard to the figures of magnetic declination published by the Meteorological Department, would that department be willing to reply to written communications as to the magnetic variations on any particular day, so that the information could be obtained without waiting for the weekly publication?

Mr. C. C. **Leach** (Seghill): I do not think that it matters much having a magnetic needle so long as you obtain a base-line to start with, as that line can be carried on by triangulation in the pit. I am of opinion that no pit can be surveyed properly by the use of the magnetic needle. You can get a north line near enough to let you know which is north and which is south from the Ordnance plans.

Dr. **Charles Chree**: In reply to Mr. Dron, the Meteorological Department at Kew Observatory would be very glad to send, on request, information as to whether on a particular day there was a magnetic disturbance or not.

Prof. E. L. **Hummel** (Leeds): With regard to the reference to Mr. Beanland's method of determining the true north line by means of a transit instrument at the top of the shaft, and by placing two marks at the bottom of the shaft in line with the line swept by the theodolite, Mr. Galloway's remarks appear to show that in his opinion it is rather difficult to obtain a good result by that means; but I can assure him that such a result can be obtained quite easily, provided that due precautions are taken. Mr. Beanland's plan has been adopted successfully on many occasions. In one instance in 1909, Prof. G. R. Thompson and I indicated successfully at the Spencer Pit, near Rothwell, Leeds, the point at which to put down a borehole to strike a 9-foot roadway at a place situated 1¾ miles from the shaft. The shaft was 11 feet in diameter, and consequently the base-line was only 10½ feet long. Special arrangements were made, and unusual care was taken, but there was no great difficulty about it—it was just the application of Mr. Beanland's method using further special precautions. A full account of the method which we used is to be found in the *Minutes of Proceedings* of the National Association of Colliery Managers,* before which society Prof. Thompson read a paper on the subject. Mr. Galloway also mentions the Severn Tunnel method, in which a very long wire was used, and it has been repeatedly stated that because of the use of this long wire a long base was obtained. It is true that a long wire was used, but naturally the shaft, at the bottom of which it was observed, had a certain diameter, and only the extreme points of the visible portion of the wire were sighted. In my opinion, the total length of the base was really the total length between the extreme end points sighted, and not the length of the wire. We can easily understand that we might extend that wire for a few hundred yards, but we could not regard those few hundred yards as a "base-line," as the base would only be the portion of the wire which was sighted from the top of the shaft. Any accuracy resulting from the use of the long wire was due, not to the wire giving a long base, but owing to its prolongation by simple mechanical means; at the same time of course it would also enable the surveyors to work at points somewhat more removed from the immediate proximity of the shafts, where they would get wet as a rule. Mr. Galloway remarks that the ordinary dial "can only be read to the nearest degree," and the smaller subdivisions "estimated by the eye." That is probably due to the existing dial being graded to degrees, and everything below having either to be estimated or read with the vernier. However, the position of the needle end can be read to a tenth of a degree between the graduations, and probably to one-twentieth of a degree or less when it is almost exactly opposite the graduations.

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* 1909, vol. vii., page 69; *Iron and Coal Trades Review*, 1909, vol. lxxix., page 8.

Dr. Chree gave us recently an exhaustive contribution on "Terrestrial Magnetism in Relation to Mine Surveying,"* and Mr. Galloway has now gone a step further and shown us how better to utilize the records of the annual and daily variations of the magnetic meridian which are now being published in the *Transactions* than is possible with the ordinary miner's dial. His instrument appears to be a very simple one which, with perhaps a little further advice from Mr. Galloway, can be easily constructed by any surveyor, at small cost. With its aid the mining surveyor will be able to determine much more readily than he can at present, the direction of the magnetic meridian, and study for himself the constant changes in its direction. With this simple instrument mine surveyors can accustom themselves to the use of a magnetic needle suspended on a fibre, and the way is paved for the more widespread introduction of the more refined instruments of the same type. Mine surveyors may then, in time, hope to be in a position to assist Dr. Chree and others in refined research into the terrestrial magnetic phenomena at great depths, as compared with the phenomena simultaneously observable at magnetic observatories at the surface. In my opinion, Mr. Galloway's paper is most opportune, following so soon upon Dr. Chree's paper, and will prove immediately helpful to all mine surveyors who care to follow up this interesting line of research.

Prof. L. H. Cooke (London) wrote: The valuable and suggestive paper by Mr. Galloway makes for progess in magnetic orientation, but the reference in its title to "determining the magnetic meridian" gives a false impression, and unfortunately lends support to an antiquated and unsatisfactory system. The title is incorrect, because the magnetic axis of his instrument will rarely or never be parallel with the mirror, as the author himself admits, and consequently the magnetic meridian will not be determined; and the title is unfortunate, because in good work, nowadays, magnetic orientation is only a stepping-stone to (*a*) the true or geographic meridian, or to (*b*) some other line of reference or "arbitrary meridian," the relationship of which to the geographic meridian is known, or the direction of which is well-established by points fixed along it with a view to their permanence, or else the line is both well fixed and truly oriented. The unhappy emphasis given by the title needs an antidote, as there are still too many upholders of the system of referring mine-surveys to the "mean magnetic meridian." In his preliminary comparison with alternative methods, the author omits to notice the shaft-plumbing orientations which are by far the most widely used at the present time where accurate correlation is necessary. With two or more shafts some hundreds of yards apart, excellent results can be secured; and even when only one shaft is available, the advances made by Fuhrmann and Wilski, and the still more striking progress obtained by Roberts, place shaft-plumbing in the front rank of all methods of correlation, so far as accuracy is concerned. Limitations of visibility are the bane of the transit-instrument method.* Mr. Richardson's modification may well have been an improvement in the shallow shafts of the Severn Tunnel, but for deep shafts the visibility of wire already obscured by falling water, finest spray, and mist, would not be increased by the vibrations the 100 yards of wire would make owing to the falling water. It is unwise to express an opinion on Mr. Galloway's magnetic reflector without seeing it: weighty criticism can come only from one who has used the instrument in his practice, and in any other circumstances adverse criticism is unfair; but one may hope to be of help by asking why an electrolytic copper or other damper has not been used. Doubtless the author has considered Brathuhn's improvement on the "Borchers magnet-collimator," whereby the suspensory silk filament, soaked in glycerine, is reduced in length to 4 centimetres (about 1½ inches)—that is, to about a sixth of its original length. The list of requisites would, of course, include extra levelling-heads for the tripods, and one of them ought to incorporate a shifting centre or slide, with plenty of play so as to facilitate the movement of the plumb-line to *C* (Fig. 1); or else the tripod at this station should have adjustable slide-legs; or it should have both such legs *and* a shifting centre. With the author's theodolite at *A*, shifting the instrument itself is preferable.

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., page 223.

The author speaks of the obliquity of the face of the mirror and the magnetic axis as a "small constant difference," which assertion begs the question. There will almost certainly be inconstancy sooner or later, but time alone can tell whether it will have any import for the interval between the two observations of any one orientation. Change at any other time is of no importance as regards accuracy. It is usual to check any such inconstancy by making a third observation on the initial line. I differ from the author as regards the best time for the observations, looking at the matter purely from the point of view of accuracy. He has evidently not been able to shake off entirely the old idea of approximating to the "mean magnetic meridian," for he specifies the evening or early morning as hours which do not deviate so much from the daily average as those made within a few hours of noon. From the point of view of irregular disturbances, the evening is an unfavourable time, while 2 a.m.

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* See Mr. H. F. Marriott's remarks in *Practical Coal Mining*, vol. vi., page 271.

till dawn* is the best time for an isolated observation that is not to be checked by another observation on an orientation line, or corrected from declination curves; but since the summer of 1895 I have consulted a large number of records of magnetic observatories and several copies of curves of magnetic declination, and I have made several underground orientations which led me to suggest† making two observations, one on the line of known orientation and the other on the line to be oriented, at the same hour on different days, one closely following the other, a suggestion which Mr. Galloway seems to approve. The principle has long been applied in precise setting-out—indeed, as long ago as 1856—but its application to the precise orientation of underground surveys has been, strangely enough, overlooked.

Mr. G. T. Newbould (Rawmarsh) wrote: It is becoming usual at new collieries to make a triangulation surface survey and to establish underground a permanent base-line having a "true" or geographical bearing, the main roads being surveyed with a theodolite and the needle used only for dial surveys of the working-places. At the great majority of collieries, however, the surface and underground surveys have for their base the magnetic meridian, and the accuracy of the plans depends entirely on the precision of obtaining the magnetic bearings on the surface and underground. An instrument calculated to render these observations more accurate is therefore of great value. Excellent results can be obtained with a large double tangent-screw telescope dial, fitted with a vernier reading to one minute, and by using a magnifying glass for setting the needle. Mr. Galloway's instrument offers an ideal method of support for the needle, and an advantage in that it is not necessary to set the needle with the eye.

Mr. T. Lindsay Galloway (Campbeltown), in reply, said: I admit that the instrument is capable of many improvements. It is not a highly-finished production so far, but it is very difficult at the present time to get any optical work done. If, however, it is found useful, I have no doubt that a much improved form can be made, although I do not think that, in principle, anything very much simpler can be devised. With regard to Prof. Tanakadate, I have not met him, but Dr. Knott drew my attention to the method used by him in Japan when surveying one section of that country. He used an instrument of his own design, in which this principle was adopted. I was aware of the method of getting rid of the torsion by replacing the magnet by an equivalent weight, but I thought it would be a rather difficult operation in connexion with mining, and that the present arrangement was really sufficient for the purpose, and very much simpler. With regard to the hour of the day at which observations can best be made, that is difficult to decide, and Dr. Chree is better able to advise than I am. I quite see the point of choosing a time when the range is at its maximum or minimum and there is less deviation going on than a time when the magnetic meridian is swinging at considerable speed. A somewhat large space has been occupied on the platform in setting up the tripods, but there could be no difficulty in reading the angles to a minute or half a minute even at a distance of 2 or 3 yards. It is really the focal length of the telescope which limits one, but that can be easily altered by any optician. One of the greatest practical difficulties has been to prevent the wind from influencing the mirror, and I have put round the sides of the apparatus an endless rubber tube, which seems to answer successfully. I hope that Dr. Knott will record the experiences in Japan of Prof. Tanakadate and himself. He told me that they carried a tent—sometimes for the sun and sometimes for the wind —and that they had little difficulty in obtaining good results.

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* *Practical Coal Mining*, vol. v., page 171.

† *Op. cit.*, vol. vi., page 280.

In reply to the correspondence, perhaps a more correct but rather high-sounding description of the subject of the paper would have been "A Method of Determining a Basis for Mining Surveys by Magnetic Observations." It is quite clearly stated in the paper itself that the primary object in view is not generally to determine the absolute direction of the magnetic meridian, but the relative directions of two lines, one above ground and one underground, or one in one part of a mine, and the other in another part. It is intended that two or more base-lines should be permanently laid down and marked, and that their relative directions should be determined by careful and repeated applications of the method described in the paper. The ease with which the observations may be repeated and checked is one of the chief advantages of this method, as compared with others which require the use of the shaft. As mining engineers are now in possession of more accurate data, and understand better the laws of magnetic variation, it seemed to the author that a method whereby any surveyor who can use a theodolite may avail himself of our improved knowledge was likely to be useful. In the introductory paragraphs of the paper allusion was made to the methods of Mr. Beanlands and Mr. Richardson, because in each of these cases the alignment was made with the aid of a telescope. Other methods were not mentioned, because they did not seem to have anything in common with the method described in the paper; but with regard to their merits the writer wishes to preserve a perfectly open mind. Some—perhaps all of them—may be useful under appropriate conditions.

As regards the cost of the magnetic reflector, the author is unable to name an exact figure, but the instrument can evidently be manufactured at a very moderate cost.

Since the meeting at Nottingham, the author has had an opportunity, through the courtesy of Dr. Chree, of examining the magnetic instruments at Kew Observatory—both those which have been formerly in use at various times and those of the most recent design. He has also had the pleasure of meeting Prof. Tanakadate in London, and learning, at first hand, his more recent experiences in two new magnetic surveys carried out about the years 1895 and 1913 respectively. He still uses, as he did in the first survey, a spider-line suspension, which, of course, necessitates the use of a very small and light mirror and magnet. He was good enough to express much interest in the application of his method of getting rid of the torsion—a method which it seems has also been used at Kew. He described a new method which he has more recently devised, but which is specially applicable to spider-line suspensions. It may be mentioned, in conclusion, that neither Dr. Chree nor Prof. Tanakadate makes use of a copper damping device.

DIGEST OF THE FIRST REPORT OF THE MINE RESCUE-APPARATUS RESEARCH COMMITTEE.*

By DAVID PENMAN.

Introduction.—In May, 1917, the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research, at the invitation of the Home Secretary, appointed a Research Committee under the following terms of reference:—

> "To inquire into the types of breathing apparatus used in coal mines and by experiment to determine the advantages, limitations, and defects of the several types of apparatus, what improvements in them are possible, whether it is advisable that the types used in mines should be standardised, and to collect evidence bearing on these points."

Owing to the unsatisfactory and sometimes fatal results obtained with some of the types of self-contained breathing-apparatus at present in use, the need for such an enquiry had become urgent. The Research Committee appointed consists of Mr. William Walker, C.B.E., H.M. Acting Chief Inspector of Mines, Dr. J. S. Haldane, F.R.S., and Dr. Henry Briggs, A.R.S.M. Mr. A. Richardson, of the Department of Scientific and Industrial Research, was appointed Secretary, and at the first meeting of the Committee Mr. Walker was elected Chairman, and Dr. Briggs Director of Experimental Work. The experimental side of the enquiry is being carried out in the Mining Department of the Heriot-Watt College, Edinburgh. As the First Report of the Committee is too lengthy to be included in full in the *Transactions*, the writer has been entrusted with the task of preparing a digest of it.

In the Report, attention is drawn to certain serious defects in existing mine rescue-apparatus and in the training of men with those appliances. The so-called "two-hour" types of breathing-apparatus using compressed oxygen are the only kinds dealt with, but subsequent reports are promised dealing with liquid-air apparatus, reviving appliances, and smoke-helmets, as well as further improvements in the two-hour type when the necessary work is completed.

For the purpose of making enquiry and inspecting apparatus and stations, the Committee visited a large number of rescue-stations throughout Great Britain. As a frontispiece to the Report, a map (Fig. 1†) is printed, showing the position of central mine rescue-stations and sub-stations in the United Kingdom. Sub-stations are indicated by italicized printing. A circle of 10 miles radius is described about each station.

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* Published for the Department of Scientific and Industrial Research by His Majesty's Stationery Office, London, price 1s. 9d. net.

† Figs. 1 to 7 have been reproduced by permission of the Controller of H.M. Stationery Office from the *First Report of the Mine Rescue Apparatus Research Committee*, 1918.

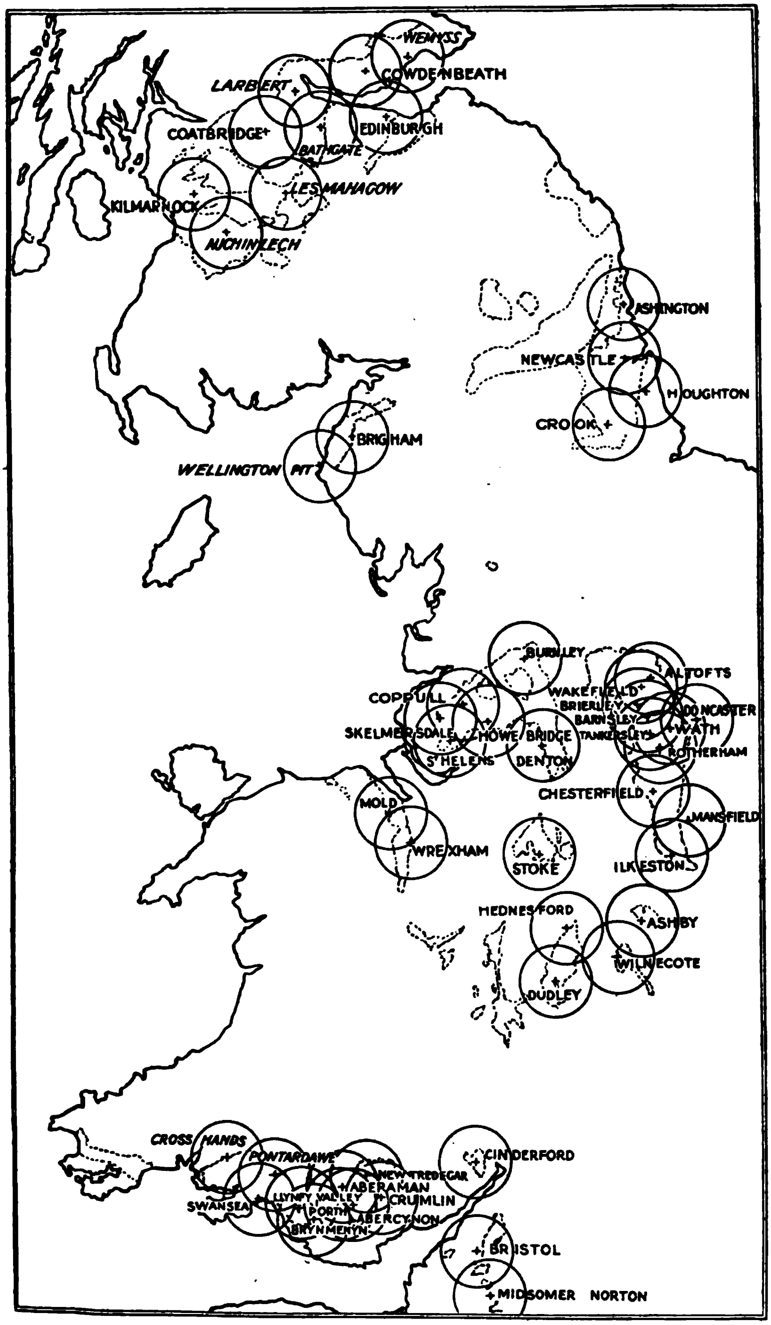
WEMYSS
COWDENBEATH
LARBERT
COATBRIDGE
BATHGATE
EDINBURGH
LESMAHAGOW
KILMARNOCK
AUCHINLECH
ASHINGTON
NEWCASTLE
HOUGHTON
CROOK
BRIGHAM
WELLINGTON PIT
BURNLEY
ALTOFTS
COPPULL
WAKEFIELD
BRIERLEY
DONCASTER
BARNSLEY
WATH
SKELMERSDALE
HOWE BRIDGE
TANKERSLEY
ROTHERHAM
S^T HELENS
DENTON
CHESTERFIELD
MOLD
MANSFIELD
WREXHAM
STOKE
ILKESTON
HEDNESFORD
ASHBY
WILNECOTE
DUDLEY
CROSS HANDS
PONTARDAWE
CINDERFORD
NEW TREDEGAR
ABERAMAN
SWANSEA
LLYNFY VALLEY
CRUMLIN
PORTH
ABERCYNON
BRYNMENYN
BRISTOL
MIDSOMER NORTON

FIG. 1.—MAP OF CENTRAL RESCUE-STATIONS AND SUB-STATIONS IN THE UNITED KINGDOM

The Report is divided into three parts, and the present summary follows the same order. It has been found necessary, however, in order to curtail the length of the paper, to re-group some of the parts. References (in brackets) are made throughout the paper to the pages in the Report where the subjects summarized are discussed. In many places the writer has found it extremely difficult to improve on the conciseness of the original, and occasionally has thought it advisable to incorporate paragraphs from the Report with as little alteration as possible.

PART I.—EXISTING SELF-CONTAINED APPARATUS.

In this section the following list of existing rescue-apparatus is given:—

TABLE I.—LIST OF EXISTING RESCUE-APPARATUS.

Name of apparatus.	Year of introduction of original model.	Nationality.	Weight, when charged, in pounds.	Nature of oxygen-supply.	Circulatory agent.	Number in use at British rescue-stations and mines in 1916.
Proto or Fleuss	1879	British ...	36	Constant feed or hand-adjusted feed.	Lungs	913
Dræger ...	1903	German	(1907 model, 36½) (1912 model, 39)	Constant feed	Injector	220
Meco, Westfalia, or Securitas ...	1906	German*	38	Constant feed	Injector	455
Weg	1906	British ...	40	Automatically controlled.	Lungs	132
Aërolith ...	1906	Austrian	22	Liquid air	Evaporation of liquid-air	Nil
Aërophor ...	1910	British ...	30	Liquid air	Evaporation of liquid-air supplemented by lungs	96
Tissot... ...	1907	French ...	32½	Hand-adjusted feed	Lungs	Nil
Gibbs	1917	American	30	Automatically controlled	Lungs	Nil
Pneumatogen	1904	Austrian	14½	By chemical action on oxylith.	Lungs	Nil

* Meco apparatus altogether made in Britain.

A brief description of each apparatus, with photographs and diagrams, is given in the Report.

PART II.—RECOMMENDATIONS REGARDING RESCUE-APPARATUS.

Part II. of the Report deals with rescue-apparatus at present in use, and enumerates important recommendations regarding the same. Attention is first of all directed to structural defects in the apparatus for which the makers are entirely responsible (page 13). It is held that the best way to secure a high standard of design and construction is to prohibit the use of breathing-apparatus in mines under the Coal Mines Act, unless the apparatus is " of a type for the time being approved by the Secretary of State." The restriction should also apply to materials supplied for charging and repairing apparatus. The Committee further propose the appointment of an inspector under the Mines Department of the Home Office, whose function would be to advise the Chief Inspector of Mines as to the safety or otherwise of breathing-apparatus in use at rescue-stations and mines, to see that the regulations concerned were properly carried out, and that all apparatus in use or intended for use were maintained in a condition fit for immediate service. That part of the regulations relating to ambulance could also be placed under this inspector's supervision (page 13). It cannot be doubted that systematic, skilled inspection and testing would greatly reduce the risks of failure of breathing-appliances in training and in actual rescue-work.

Causes of Failure of Apparatus.—The Committee consider that the foremost requisite of an efficient form of mine rescue-apparatus is that it should be capable of protecting the wearer for at least two hours during any kind of work he may have to attempt (page 14). The apparatus should permit of heavy exertion during, at any rate, part of the two hours, including especially the last part. The commonly-held opinion that rescue-apparatus is not meant for strenuous work—an opinion based on experience of the inability of certain forms of rescue-apparatus to sustain the wearer during prolonged periods of hard work—must give place to the view that an apparatus is inadequate and virtually unsafe unless it satisfies the requirements outlined above. Actual rescue- and recovery-work in a mine may, and generally does, call for heavy exertion, and unless the apparatus worn provides a fair margin of security during the period of greatest demand, it cannot be considered adequate or safe. An apparatus may fail on account of any one or more of the following causes:—

(1) *Failure through Accumulation of Carbon Dioxide* (page 14). This is the chief cause of failure of some of the types of apparatus at present in use. The danger-point in breathing is reached when the percentage of carbon dioxide in the air contained in the lungs amounts to about 10 or 11 per cent. During

heavy work this percentage will be reached when the percentage of carbon dioxide in the inhaled air reaches 4 to 6 per cent. Accumulation of carbon dioxide in the inhaled air to this extent may be due to (*a*) a portion of the exhaled air being re-breathed without its having passed through the purifier, or (*b*) failure of the purifier to remove the carbon dioxide in the air passing through it. Apparatus of the injector type are particularly liable to the former defect, because during heavy work the respiratory demand may exceed the circulation due to the injector, and thus part of the inspired air must be re-breathed without having been purified. The dead space in the helmet form of apparatus is a bad feature, which tends to augment the accummulation of carbon dioxide in the inspired air. Lung-operated mouthpiece apparatus, if the valves are in good order, are practically free from this serious defect. Failure of the purifier to absorb the carbon dioxide passed through it may be due either (*a*) to insufficient quantity of absorbent, or (*b*) to faulty arrangement of the air-passages in the purifier, allowing serious proportions of carbon dioxide to pass through it without coming into effective contact with the absorbent. It is pointed out (page 30) that caustic soda is less active when cold than when it has been warmed slightly. The Committee strongly advocate that the purifier should be so constructed as to outlast the oxygen supply. The test they recommend as a standard is to see whether the purifier will last for two hours or till the oxygen is exhausted with the wearer walking on the level at 4 miles per hour. The absorption of carbon dioxide may be considered satisfactory if the proportion of this gas in the inhaled air from the apparatus does not exceed 2 per cent. at the end of the test period.

(2) *Failure of the Oxygen Supply.*—Numerous matters relating to the oxygen supply are discussed under various headings. The writer has grouped all such under the above general title. Failure of the oxygen supply may be due to:—

(*a*) The oxygen supply falling short.

(*b*) The main cylinder-valve being closed by the wearer (or accidentally) during work.

(*c*) The main valve being insufficiently opened.

(*d*) The oxygen feed being insufficient for the requirements of the wearer.

(*e*) The oxygen flow being stopped by rust particles.

(*f*) The oxygen used not being sufficiently pure.

(*a*) *The Oxygen Supply may Fall Short* (page 15).—This is usually due to leakage at connexions, at valves, or, in the case of the helmet or face-mask, at the face-joint. When the oxygen is carried in cylinders, the pressure-gauge affords a ready means of ascertaining the supply of oxygen at the commencement and during use. With liquid-air apparatus this indication is absent, and other safeguards must be used. The importance of testing the pressure-gauges is emphasized, several instances of their occasional unreliability having been brought to the notice of the Committee (page 30). An untrustworthy gauge is a source of grave danger during active work. The installation at rescue-stations of the simple and inexpensive arrangement designed by Dr. Briggs and illustrated by Fig. 2 is advocated. It allows of gauges (*gg*) being compared, six (or less) at a time, against a standard gauge *G*, calibrated at the National Physical Laboratory, Teddington, and checked there once a year. A small oxygen cylinder *C*, charged to 120-150 atmospheres, is attached to the appliance and the oxygen turned on. After the gauge readings have been taken, some of the gas is exhausted by means of the tap *T*, when the gauges are again compared. In this way any number of readings is obtainable between the initial pressure and zero.

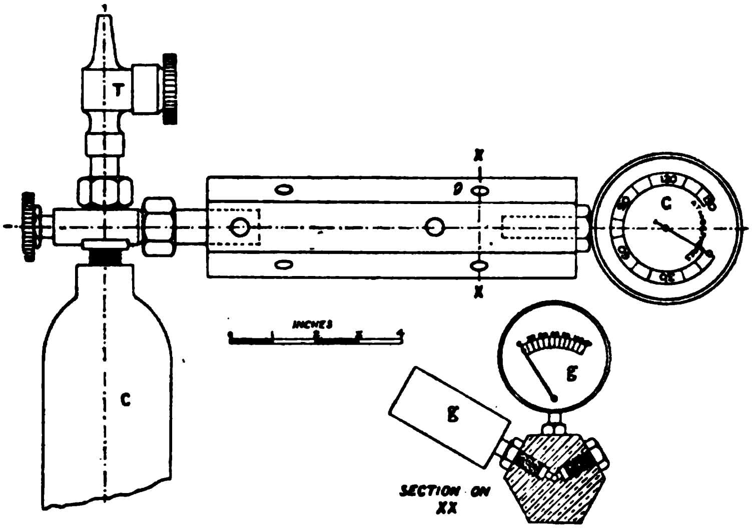

FIG. 2.—APPLIANCE FOR TESTING PRESSURE-GAUGES.

(*b*) *The Main Oxygen-valve may become Closed during Work* (page 18).—Cases are cited of the actual closing of the oxygen-valve during rescue-operations. The death of Captain Ramsay, Superintendent of the Elswick (Newcastle-upon-Tyne) Station on June 6th, 1913, was due to this cause, as the valve was found shut. A similar occurrence, fortunately not attended with fatal results, took place during tests of the Proto apparatus at Mansfield in 1917. Several cases are recorded of men on starting a practice turning off their oxygen under the impression that they were turning it on, and of others forgetting to open the oxygen-valve before closing the apparatus and applying the nose-clip. In order to avoid occurrences of the kind, the main oxygen-valve should be so arranged that it is impossible for it to be turned off accidentally while the apparatus is in use. The device recommended in the Report is shown in Fig. 3 (page 19).

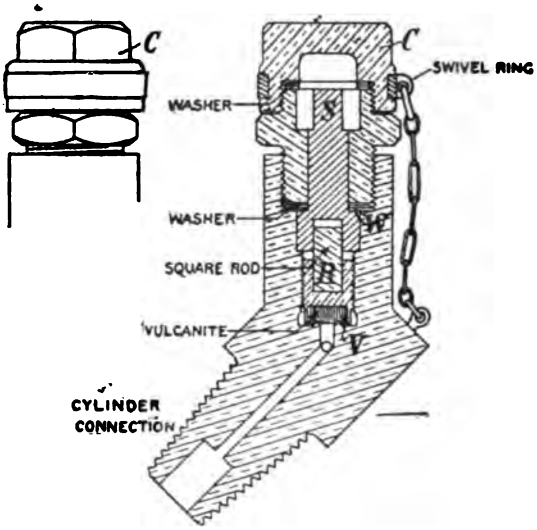

Fig. 3.—Sunk-spindle Valve.

It consists of a sunk-spindle valve protected by a screw-cap C. A double-ended key (Fig. 4) is provided to suit the square-ended valve-spindle S and the screw-cap. The screw-cap prevents the escape of oxygen in case of leakage along the spindle—a common defect.

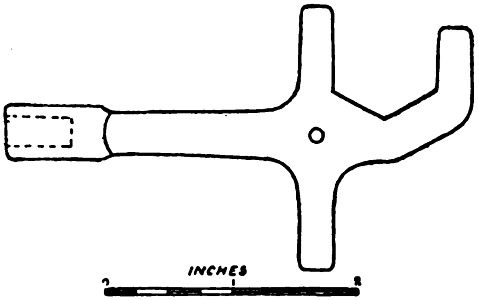

Fig. 4.—Key for Sunk-spindle Valve.

(*c*) *The Main Oxygen-valve Insufficiently Opened* (page 19). —It is suggested that wearers of rescue-apparatus should be warned against insufficiently opening the main oxygen-valve. When the pressure in the cylinders is high, a fraction of a turn may allow a sufficiently rapid flow; but, as the pressure falls, the flow may become checked. The valve should, therefore, always be fully opened. The main valve of the older Proto apparatus is severely criticized (page 19). With this valve, when not provided with a locking device, it is possible to continue unscrewing until the valve spindle is withdrawn, when all the oxygen is at once lost. A further drawback of the valve is the difficulty of preventing leakage round the spindle. Moreover, the packing round the spindle consists of asbestos-graphite, which continually flakes off. The graphite flakes may, and often do, get into the reducing-valve, in which case they may cause a stoppage of the flow of oxygen (page 26). The newer Proto valve, which is similar to the Meco and Dræger valves, is much superior, and all Proto apparatus should be refitted with the newer valve.

(*d*) *Insufficient Oxygen Feed* (page 20).—The danger arising from the oxygen percentage in the air breathed falling below that in normal air is pointed out (page 15). One of the causes of this is the fixing of the oxygen feed at too low a valve. Disastrous results may follow an insufficient feed, as has been recently tragically demonstrated by the death of H. Doorbar at the Podmore Hall Colliery disaster in January, 1918 (page 21). The apparatus worn by Doorbar was tested by Dr. Briggs, and the reducing-valve was found to be out of adjustment. The reducing-valve passed only 1·56 litres of oxygen when the cylinder pressure was 120 atmospheres, and 1·17 litres when the pressure had fallen to 35 atmospheres. In Dr. Briggs's report on the accident this low feed was stated to be a contributory cause of the collapse of Doorbar and his subsequent death from carbon-monoxide poisoning. Drs. Haldane and Briggs have made measurements of the consumption of oxygen by men wearing rescue-apparatus while climbing inclines and breathing ordinary air. A second Report is promised giving fuller particulars, but a few average results are included (page 20).

TABLE II.—SHOWING CONSUMPTION OF OXYGEN IN CLIMBING VARIOUS GRADIENTS.

Gradient of roadway.	Average speed, in miles per hour.	Average oxygen-consumption, in litres per minute.
1 in 6¼	2·15	1·49
1 ,, 5	2·05	2·12
1 ,, 3½	1·62	2·32
1 ,, 2	1·06	2·60

The rapid lowering of the oxygen-percentage in the breathing-apparatus may be further accelerated by the practice of filling the breathing-bag with air at the commencement (page 15). This is or has been the custom at some stations, and is held to be highly reprehensible. It was probably a contributory cause of the death of Doorbar. In order to obviate the risk attendant on a low rate of supply, it is recommended that both the bag and the lungs be washed out with pure oxygen at the start. The method of procedure advocated in closing the apparatus upon the person is as follows:—

Begin by sucking the bag flat and exhaling through the nose. The oxygen is turned on, the mouthpiece orifice closed by the tongue, and the bag allowed to fill up. The bye-passes on the Proto and Weg apparatus allow this to be done quickly. A deep breath is next drawn from the apparatus and exhaled through the nose. The nose is now clipped. It is also recommended that

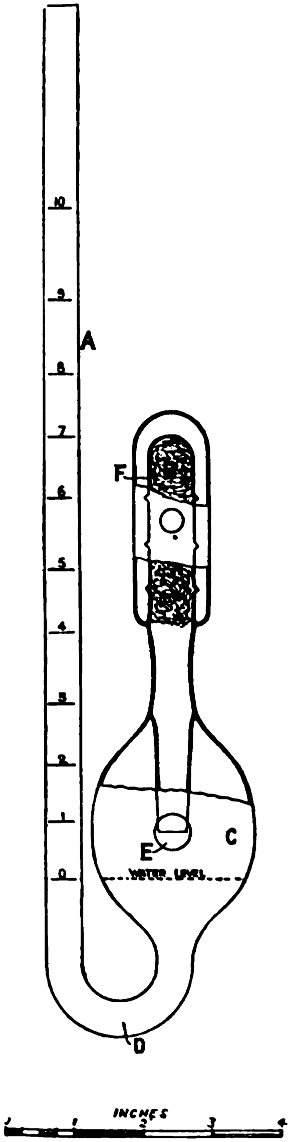
10
9
A
8
7
F
6
5
4
3
2
1
C
E
0
WATER LEVEL
D
INCHES
1
2
3
4

Fig. 5.—Haldane Litre-meter.

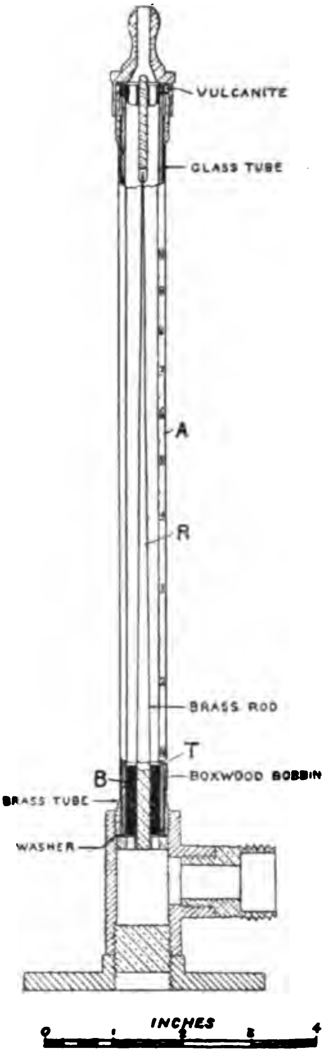
VULCANITE
GLASS TUBE
A
R
BRASS ROD
T
B
BOXWOOD BOBBIN
BRASS TUBE
WASHER
INCHES
0
1
2
3
4

Fig. 6.—Briggs Litre-meter.

unless the relief-valve automatically discharges from time to time as the work proceeds, the bag should be squeezed empty and filled up afresh with oxygen before heavy work is attempted. The wearer thus starts on practically pure oxygen (page 27).

A minimum rate of oxygen-feed is prescribed by the Committee (page 21). They recommend that in the case of any breathing-apparatus dependent on a uniform oxygen delivery, it should be made illegal to adjust the reducing-valve to supply less than 2 litres per minute. The practice adopted at certain stations where the Proto apparatus is in use of having a lower rate of feed than 2 litres per minute is strongly condemned. It is pointed out that the lower inhaled-air temperature attributed to a low oxygen-feed can only be due to a decrease in carbon dioxide exhaled and absorbed, which in turn can only result from less physical work (page 20). In plain words, if the wearer takes it easily, he will consume little oxygen and expel little carbon dioxide; but these conditions could not be secured in actual rescue operations, nor should they be aimed at in practices. Another reason given for using a low oxygen-feed is the less highly-distended state of the breathing-bag (Proto apparatus). To prevent undue distension of the breathing-bag, the substitution of the automatic relief-valve used on other types of apparatus is advocated for the Proto hand-actuated blow-off (page 20). As a means of providing (*a*) extra oxygen if the wearer should feel the need of it, (*b*) a means of quickly filling the breathing-bag after it has been purposely or accidentally flattened, and (*c*) an extra channel from the cylinder to the circuit, which, in the event of the failure of the oxygen-supply through the reducing-valve, could suffice to allow the wearer to make good his escape, the Committee recommend the adoption on every apparatus using compressed oxygen of a bye-pass such as is fitted to the Proto and Weg apparatus (page 27).

The measurement of the oxygen-feed is one of the most important tests that have to be applied from time to time to the apparatus, and the report describes and illustrates several forms of flow-meters, including two types designed respectively by Drs. Haldane and Briggs (Figs. 5 and 6).

(*e*) *The Oxygen Flow may be Stopped by Rust-particles* (page 25).—Attention is drawn to the rusting of oxygen-cylinders and the consequent danger of the rust-particles interfering with the oxygen flow. Cylinders of three apparatus were examined, and all contained rust-particles, one being particularly bad. In the Weg cylinder an effective attempt is made to prevent the rust-particles from being carried out of the oxygen-cylinders. A tube 4 inches long projects into the cylinder. The tube is closed at its inner end, but has an opening at the side, which is covered with a fine gauze and this forms an effective trap. In other cylinders such as the Proto, gauzes are used which, although not preventing the rust from getting out of the cylinder, yet help to prevent it from getting into the reducing-valve where the greatest danger lies. While considering gauzes a valuable safeguard, the Committee think that the best way of coping with rust and scale is to prevent its formation. They recommend scouring the inside of the cylinders immediately after annealing. A coat of varnish should then be given to the inside of the cylinder. The process is fully described in the Report. Eventually some mode of protection superior to varnishing may be discovered. Single oxygen-cylinders, such as are used in the Gibbs, Tissot, and new Dræger apparatus, are to be preferred to double cylinders, as the need for a narrow-bore connecting-piece is then dispensed with.

(*f*) *Impurity of the Oxygen Used* (page 28).—The regulations require that the oxygen used in rescue-apparatus should have at least a purity of 98 per cent. Several instances have come to the notice of the Committee of oxygen of a less degree of purity than this being supplied and used. Prof. Sir John Cadman found that the oxygen used by two men who died at the Newdigate Colliery, Warwickshire, on October 8th, 1916, was only 96·8 per cent. pure. Dr. Briggs analysed fourteen samples of oxygen from ten different stations, and of these found only six of the required standard of purity. Mr. J. Ivon Graham, Chief Chemist at the Doncaster Coal Owners' Laboratory, also analysed fourteen samples, and found that only three conformed to the standard, and one contained less than 80 per cent. The situation revealed by those analyses is characterized as grave, and the remedy suggested is that it be made obligatory to analyse the oxygen from every cylinder supplied for use in connexion with self-contained apparatus, whether at rescue-stations or at individual mines. Oxygen containing over 2 per cent. of impurity should not be used in actual work, underground practices, or in any situation where a member of a brigade may get out of sight of the instructor; oxygen containing over 5 per cent. of impurity should not be used in any circumstances. With lung-controlled apparatus, such as the Weg or Gibbs, or apparatus in which the oxygen-supply can be cut down by the wearer, the purity should be over 99 per cent. In the case of electrolytic oxygen, when the impurity contains hydrogen in addition to nitrogen, the Committee consider that unless the oxygen-percentage exceeds 99½ per cent. the hydrogen proportion should also be ascertained. If the percentage of hydrogen in any instance exceeds ½ per cent., the oxygen should not be used in a self-contained breathing-apparatus. The reason given for the greater stringency advocated in the case of electrolytic oxygen is that whereas accumulation of nitrogen or argon simply reduces the percentage of oxygen in the air breathed, hydrogen, in addition to doing this, may also form an explosive mixture with the oxygen in the apparatus. In the American Report instances are given of samples of electrolytic oxygen having as much as 3 to 4 per cent. of hydrogen. It was found in a test with certain apparatus using oxygen containing slightly more than 1 per cent. of hydrogen that the percentage of hydrogen within the apparatus at the end of two hours had reached 23. This forms a violently explosive mixture. It is pointed out that the references as to the purity of the oxygen do not apply to liquid-air apparatus.

For the purpose of facilitating the analyses of oxygen, two forms of analysis apparatus have been designed expressly for testing almost pure oxygen. One of these is due to Mr. Graham of the Doncaster Coal Owners' Research Laboratory and the other to Dr. Briggs. Both are fully described and illustrated in Appendix II. of the Report.

(3) *Leaky Apparatus.*—An apparatus may fail on account of leakage (page 16). Inward leakage is more serious than outward leakage: for whereas the latter leads to the exhaustion of the apparatus and perhaps the flattening of the breathing-bag, the former admits poisonous gases. Leakage may occur at joints, through punctures, in tubes or breathing-bag, or at the face-connexion. Escape of high-pressure oxygen may be detected by the hissing noise, or by an unduly rapid fall of the pressure-gauge. In the other parts of the apparatus leakage may be either outwards or inwards, or in both directions. Injector apparatus are more prone to inward leakage than apparatus which do not use an injector, but the latter are not free from the defect. The mouthpiece is considered to be more airtight than the helmet or face-mask, and this advantage, taken in conjunction with the fact that the mouthpiece eliminates dead space, is given as the grounds for recommending that the known types of helmet and face-mask should be abolished in so far as self-contained apparatus are concerned (page 18).

It is pointed out that the greatest danger arises from the possibility of carbon monoxide finding its way into the apparatus. Blackdamp and firedamp drawn in will only reduce the percentage of oxygen in the breathing circuit, and if the oxygen-supply is ample and constant, the risk may not be great. In apparatus such as the Weg or Gibbs, however, inward leakage of these gases, or even of pure air—at, say, a point in the inspiratory tube—would be dangerous in that it may be the cause of the oxygen-supply failing. The effects of carbon monoxide on the system are described (page 16). The correct treatment of a person who has collapsed from carbon-monoxide poisoning while wearing breathing-apparatus is to keep the patient breathing as much pure oxygen as possible until he has been removed to innocuous air and for some time after he regains consciousness. The patient should be kept as warm as possible.

Apparatus should be frequently tested for leakage, and every brigade member should be familiar with the method of testing (page 31). The best test is to immerse the whole apparatus in water with the oxygen turned on and with the mouthpiece closed by the thumb. As the breathing-bag becomes distended, the increasing pressure within will cause bubbles to rise from faulty joints or punctures. Leakage of high-pressure oxygen is seen at once. Belts, slings, and coverings should be removed before the apparatus is subjected to the test. The Committee suggest that a suitable receptacle, such as a collapsible bath, should be added to the rescue-station equipment for the purpose of carrying out the test. All apparatus for use in poisonous air should have passed this test prior to such use.

(4) *Failure through the Inspiratory Breathing-bag becoming Empty.*—In order to be capable of satisfying the needs of the wearer, there must always be a sufficient volume of air in the inspiratory breathing-bag to allow him to inhale a full breath. If from any cause the bag becomes so empty that a full breath cannot be drawn from it, panic may ensue which may be the indirect cause of disaster. This is especially the case if the bag has collapsed suddenly. Collapse of the breathing-bag may result from (*a*) leakage, (*b*) accidental pressure on the bag, or (*c*) premature action of the automatic relief-valve through excessive breathing, accompanied perhaps by partial choking of the purifier (page 17).

(5) *Failure due to Excessive Resistance to Breathing.*—Excessive resistance to breathing may be due to (*a*) choking of the purifier, (*b*) sticking of the valves, (*c*) insufficient area of air-passages, or (*d*) a highly-distended apparatus resulting from the relief-valve failing to operate. Great discomfort and even distress to the wearer may result from this cause. No apparatus is to be considered satisfactory in which, while walking at 4 miles an hour, there is discomfort due to any of the above causes (page 17).

(6) *Failure due to Excessive Temperature of the Inspired Air.*—This matter is to be treated fully in a subsequent Report, but the statement is made that an apparatus should be regarded as unsatisfactory if the wet-bulb temperature of the inspired air exceeds 105° Fahr. (40½° Cent.) under the temperature conditions commonly met with in mines (page 17).

(7) *Failure due to Rise in Body Temperature.*—If the wet-bulb temperature of the mine exceeds 80° Fahr., the wearer of

an apparatus may be overcome by the rise in his own body temperature. Heat from the purifier may hasten this rise in temperature. In hot mines unnecessary clothing should be discarded, excessive exertion avoided, and the body protected from the heat of the purifier. The effects of high wet-bulb temperature should be experienced by men during training, so that they may know how to guard against risks from this cause (page 17).

(8) *Failure due to Faulty Construction or Material.*—The opinion is expressed that only the best and most suitable material should be employed in making rescue-apparatus, and only the best workmanship and finish should be permitted. All pipes and fittings should be so fixed as not to be liable to get damaged or detached by contact with projections in the passages of the mine, and the apparatus ought to incommode the wearer as little as possible (page 17).

Apparatus using an Injector.—Apparatus in which an injector is employed to induce the circulation of air are subjected to severe strictures. The limited amount of air in circulation is held to be a bad feature, and to be a source of grave danger when the volume of air breathed becomes greater than that circulated by the injector (page 23). Provision is made in both the Meco and the Dræger apparatus to enable the wearer, during periods of heavy exertion, to inhale more air than the quantity circulated; but the result in both cases is that unpurified exhaled air is used to make up the indrawn volume to the lungs' requirements. These expedients are looked upon by the Committee with the gravest suspicion (page 24). Lengthy reference is made to the accident at the Duchy Colliery, South Wales. in March, 1917, when two men lost their lives (page 22). The Dræger apparatus was in use, and the fatal results were attributed partly to defects of the injector arrangement and partly to faulty purifiers. With the helmet form of apparatus, the injector system was practically a necessity; but with the abolition of the helmet, the need for the injector completely disappears. The cooling effect of the injector, claimed as an advantage, is proved to be quite small in magnitude.

Another danger, first commented upon by Prof. Sir John Cadman, arises from the fact that the injector is liable to create a negative pressure in those parts of the apparatus immediately behind it (page 23). This is a grave danger, for a leak in the negative-pressure zone would result in an inflow from the outer atmosphere. One death is known to have been due to this cause.* Again, if a person wearing an injector apparatus should, when in a poisonous atmosphere, have his mouthpiece knocked out, air will be drawn from the surrounding atmosphere into the apparatus (page 24). A test was run on a Meco apparatus with the mouthpiece in an atmosphere containing 2·73 per cent. of carbon monoxide. Samples taken from a tap on the inhalation tube at 1, 2, and 4 minutes after starting the oxygen-supply revealed 0·30, 0·36, and 0·41 per cent. of carbon monoxide. Lung-operated apparatus such as the Proto or Weg are free from this danger. Attempts have been made to construct positive-pressure injector apparatus, but these, while being improvements, have only partly eliminated the dangers referred to. Another drawback to the injector is its liability to become choked. The Committee conclude a minute examination of injector apparatus by recommending that the injector be abolished in all future rescue-apparatus, and that existing apparatus be altered as soon as practicable in order to eliminate it (page 25).

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* *Trans. Inst. M. E.*, 1912-1913, vol. xliv., page 463.

Testing of Apparatus.—A thorough test should be made of every breathing-apparatus at a rescue-station or mine at least once a month. A record should be kept of the results of the tests. Particular attention should be paid to (*a*) the oxygen flow, (*b*) the pressure-gauge, (*c*) the automatic relief-valve, (*d*) the condition of the mouthpiece, and (*e*) the airtightness of the apparatus.

PART III.—TRAINING OF RESCUE-BRIGADES.

This portion of the Report deals with the organization and training of rescue-brigades, and the proper mode of procedure in actual rescue-operations. It is pointed out that this subject is of equal importance to that relating to the selection of suitable apparatus: for rescue-apparatus, no matter how perfect, is useless unless worn by properly-selected and thoroughly-instructed men.

Some remarks are made with regard to the training-gallery. The aim should be to make the gallery resemble the roadway of a mine after an explosion. The gallery at Wath-on-Dearne is cited as an excellent example of this pattern. The floor is formed of broken shale, and is made very irregular; here and there zones of displaced timber are arranged; provision is made for heating the air in addition to making it irrespirable. A dark underground practice-ground, such as those at the Wakefield and Chesterfield Stations, is a valuable addition to the ordinary training-gallery. At the Wakefield Station bare signal-wires are carried into both galleries, and are connected to a loud bell in the observation court. This enables the signal code to be practised, and furnishes a means of giving warning if anything untoward occurs (page 34).

Rescue-station Organization.—The Regulations relating to rescue-training may be complied with in three ways, as under:—

(1) The mine may be connected to a neighbouring rescue-station maintaining a resident brigade.

(2) The mine may be connected to a station at which there is no resident brigade, the brigades being altogether formed of employees of the mines.

(3) The mine may be unconnected with a rescue-station, the whole work of training men and maintaining the necessary apparatus being undertaken at the mine.

As between the first two alternatives, the opinion is expressed that the choice depends largely on the size of the station's district, and the character of the mines to be served. With large and populous districts, the permanent-brigade system involves less work on the station staff and less wear and tear on the apparatus. In addition, the resident brigade becomes more familiar with the apparatus than does a colliery brigade. The Committee, however, are doubtful whether, on the occasion of rescue- or recovery-work involving uninterrupted work over a long period, there would always be a sufficiency of reserve teams under the resident-brigade system to carry on operations. They recommend that trained men at mines served by a station should be grouped together as far as practicable into definite brigades, with at least five members in each to train and practice together (page 37). The view is expressed that there should be at least two competent persons employed at even the smallest central station—some stations at present have only one official (page 38). If the system of non-resident brigades is in use, there should be not less than two competent persons at the station when the number of trained colliery brigades is less than fifty, not less than three when the number of brigades lies between fifty and one hundred, and not less than four when the brigades exceed one hundred in number. For the resident-corps system the number of competent persons, in addition to the permanent corps, should not be less than two in any case, and not less than three if the number of underground employees at all the mines served by the station exceeds 15,000. The term " competent person " means an officer capable of taking charge of all the work to be done at or in connexion with the station (page 38).

In the case of unattached mines, the Committee, while recognizing that the instruction given at some of those mines is of a high standard, consider that such mines within range of a central station are a source of weakness and possibly of danger, and advocate that no coal-mine within a 10-mile radius of a central rescue-station should be permitted to remain unattached to the station (page 34).

A modification of the resident-brigade system submitted by Mr. David Stevenson of Cowdenbeath Rescue-station, meets with apparatus (page 24). A test was run on a Meco apparatus with the mouthpiece in an atmosphere containing 2·73 per cent. of carbon monoxide. Samples taken from a tap on the inhalation tube at 1, 2, and 4 minutes after starting the oxygen-supply revealed 0·30, 0·36, and 0·41 per cent. of carbon monoxide. Lung-operated apparatus such as the Proto or Weg are free from this danger. Attempts have been made to construct positive-pressure injector apparatus, but these, while being improvements, have only partly eliminated the dangers referred to. Another drawback to the injector is its liability to become choked. The Committee conclude a minute examination of injector apparatus by recommending that the injector be abolished in all future rescue-apparatus, and that existing apparatus be altered as soon as practicable in order to eliminate it (page 25).

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(1) The mine may be connected to a neighbouring rescue-station maintaining a resident brigade.

(2) The mine may be connected to a station at which there is no resident brigade, the brigades being altogether formed of employees of the mines.

(3) The mine may be unconnected with a rescue-station, the whole work of training men and maintaining the necessary apparatus being undertaken at the mine.

As between the first two alternatives, the opinion is expressed that the choice depends largely on the size of the station's district, and the character of the mines to be served. With large and populous districts, the permanent-brigade system involves less work on the station staff and less wear and tear on the apparatus. In addition, the resident brigade becomes more familiar with the apparatus than does a colliery brigade. The Committee, however, are doubtful whether, on the occasion of rescue- or recovery-work involving uninterrupted work over a long period, there would always be a sufficiency of reserve teams under the resident-brigade system to carry on operations. They recommend that trained men at mines served by a station should be grouped together as far as practicable into definite brigades, with at least five members in each to train and practice together (page 37). The view is expressed that there should be at least two competent persons employed at even the smallest central station—some stations at present have only one official (page 38). If the system of non-resident brigades is in use, there should be not less than two competent persons at the station when the number of trained colliery brigades is less than fifty, not less than three when the number of brigades lies between fifty and one hundred, and not less than four when the brigades exceed one hundred in number. For the resident-corps system the number of competent persons, in addition to the permanent corps, should not be less than two in any case, and not less than three if the number of underground employees at all the mines served by the station exceeds 15,000. The term " competent person " means an officer capable of taking charge of all the work to be done at or in connexion with the station (page 38).

In the case of unattached mines, the Committee, while recognizing that the instruction given at some of those mines is of a high standard, consider that such mines within range of a central station are a source of weakness and possibly of danger, and advocate that no coal-mine within a 10-mile radius of a central rescue-station should be permitted to remain unattached to the station (page 34).

A modification of the resident-brigade system submitted by Mr. David Stevenson of Cowdenbeath Rescue-station, meets with approval, and it is suggested that regulations be drafted to allow of this system being adopted where it is desired (page 38). In this scheme, in place of having the permanent corps continuously employed at the station, the members would pursue their calling at one or more of the neighbouring mines. They would live at or in the vicinity of the station, and in the latter case be in telephonic communication therewith. The scheme is sketched in full in the Report.

Selection of Brigade Members.—In selecting members of rescue-brigades, the suggestion is made that, in addition to the ordinary medical examination, which at present is the only test of suitability, a physical test, involving a spell of heavy exertion either on the ergometer or in running or stair-climbing, should be applied. The chief technical officer at a rescue-station should have power under the General Regulations of rejecting any person whom he considers physically, mentally, or temperamentally unsuitable for a place in a rescue-team, even though the person should possess a medical certificate to the effect that he is organically sound. The officer should also have power to discharge from a team a trained man if for any good reason he should consider the man unfit to continue as a brigade member. The Committee prefer that the medical examination should be made by an independent doctor at the station rather than by the local doctor, holding that this plan affords a more uniform standard and facilitates co-operation between the doctor and the instructor. They also suggest that every member of a rescue-team or corps should be medically examined once a year (page 35).

Twenty-three years is suggested as the lower age-limit for an acting member of a rescue-brigade. Younger men may be allowed to undergo training, but not to form one of a brigade. No person over 45 years of age should be allowed to undergo training, and no ordinary member of a brigade should retain his position after he reaches the age of 50 years. In the case of mine officials, however, and especially those acting as captains of rescue-teams, owing to their great value as leaders, it is preferable not to adopt any fixed upper age-limit, but to leave each case to be judged on its merits (page 36).

Training of Brigade Members: Quarterly Practices.—The recommendations respecting quarterly practices may be summarized as follows:—

(*a*) Although there seems to be no necessity for prescribing a greater number of practices per year than four, it may be advisable in many cases to hold more frequent meetings of rescue-brigades (page 36). At the new Tredegar Station, brigades do six trainings per year.

(*b*) Underground practices are essential, and that part of the

Regulations requiring at least two practices per year to be undergone at the mine should be strictly observed (page 37). In some instances it is stated that no underground practices are being carried out. It is pointed out that underground work, and especially the climbing of an incline, is much more severe work than the kind of labour usually performed in a station gallery, and is a more stringent test of the capability of the apparatus and its wearer. Reference is made to the loss of two trained men at the Duchy Colliery, Pontycymmer, on March 2nd, 1917, as indicating that an apparatus may behave satisfactorily in a gallery, but fail disastrously in the pit (page 22).

(*c*) It should be made compulsory for resident brigades to undergo at least six underground practices with breathing-apparatus every year; these practices should, as far as possible, take place at different mines, and the corps on each occasion should be accompanied by trained men connected with the mine, who should also wear breathing-apparatus (page 37). It should be permissible for the instructor to divide the corps into two or three squads, so that while one squad underwent practice in the pit there would still be left sufficient men to attend adequately to the station. Also one-half of the practices of the trained men employed at the mines should take place underground.

Instruction of Members of Brigades.—A portion of General Regulation 140 (*d*) reads as follows:—

> "The members of the brigade shall have received instruction in the reading of mine plans, in the use and construction of breathing apparatus, in the properties and detection of poisonous or inflammable gases, and in the various appliances used in connection with mine rescue and recovery work."

Chiefly on the grounds of insufficiency of staff, rescue-station instructors, with some exceptions, have neglected this regulation. The difficulty of lack of staff would be removed if the number of persons competent to give this instruction at the station were prescribed by law according to the Committee's proposals. One hour should be devoted to instruction in the subjects set forth in the Regulations at each of the twelve trainings (page 39). In the Report the subjects are dealt with in the following order:—

(*a*) *Gas-detection* (page 39).—The brigade member should be familiar with the properties of firedamp, blackdamp, and whitedamp. Men possessing the fireman's or shot-firer's certificate could be excused that part of the instruction that relates to firedamp. The percentage of blackdamp in the mine air (or conversely the oxygen-percentage) may be determined by Dr. Haldane's tube-and-paper test,* or by Dr. Briggs's oxymeter safety-lamp.† The extinction-point of the different lamps in use should be noted, and attention should be drawn to the insensitiveness of a bird or of a man to even large percentages of firedamp or blackdamp.

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* *Trans. Inst. M. E.*, 1910-1911, vol. xli., page 455.

† *Ibid.*, 1915-1916, vol. li., page 169.

The method suggested of demonstrating in a practical manner the influence of carbon monoxide is to have a bird placed in a cage, into which is passed air containing ordinary lighting-gas in known proportion. The percentage of carbon monoxide in the gas can be obtained from the town gas engineer, and the proportions of gas to air calculated, so as to secure known small percentages of carbon monoxide. The other constituents of lighting-gas may be considered as inert, the percentages used being small. The time elapsing between the moment of insertion of the bird into the gas and the first indications of gas-poisoning should be noted for different percentages, particularly for proportions between ½ and 1 per cent. The time to produce collapse and the time required for the animal to recover, first in fresh air and then in oxygen, should also be demonstrated.

Several forms of apparatus specially designed for teaching gas-detection are mentioned. The airtight chamber fitted with observation windows, and with provision for obtaining varying percentages of gases in the atmosphere of the chamber, is recommended as a good method of studying the properties of mine gases and their effect on the individual. In such a chamber the efficiency of rescue-apparatus as a protection against deleterious gases may be conveniently demonstrated. It is pointed out that carbon dioxide, nitrogen, and pit firedamp may be obtained in compressed form in steel cylinders, the two former gases through the larger chemical dealers and the last from Messrs. Insoles, Limited, Porth, South Wales. The Committee consider that advantage should be taken of local mining schools for the furtherance of instruction of rescue-brigades in gas-detection (page 40).

(*b*) *Plan-reading* (page 40).—The method suggested of imparting instruction in plan-reading is the following:—Copies of simplified plans such as those used in the examinations for mine managers' certificates are available, and large wall-diagrams of the same plans should be prepared by the station staff. The large plan is "ventilated," and with the aid of explanations from the instructor the men mark their copies to correspond. More advanced instruction should include the examination of the actual ventilation plans of neighbouring pits, and this would be greatly facilitated if mine managers made a rule of forwarding to the rescue-station the tracings made in compliance with General Regulation 142 (*b*) as soon as they are superseded by others. In order to systematize instruction in plan-reading, a uniform code of conventional signs for ventilation plans is recommended. The code is given as an appendix to this summary. Fig. 7 shows a "ventilated" plan, in which the foregoing signs are used, but different shadings have been substituted for the red and blue on the original plan, indicating the return and intake airways respectively.

(*c*) *Construction and Testing of Apparatus* (page 41).—The necessity for all members of resident brigades being thoroughly familiar with the apparatus in use at their station is emphasized.

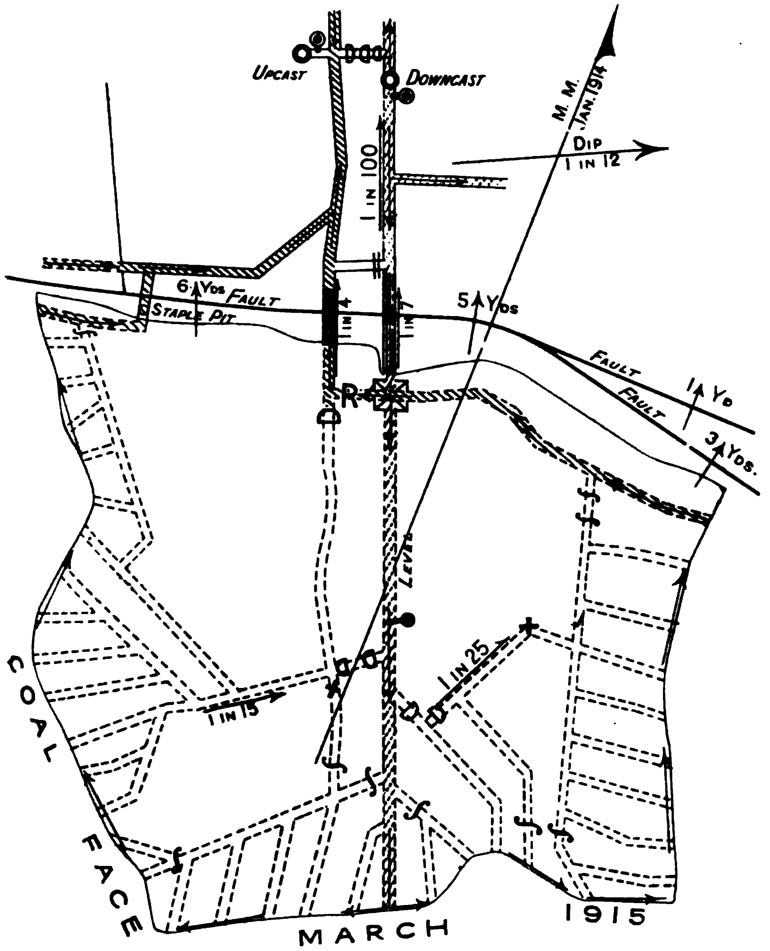
Upcast
Downcast
M. M. Jan. 1914
Dip 1 in 12
1 in 100
6 Yds
Fault
Staple Pit
5 Yds
Fault
Fault
1 Yd
3 Yds.
R
Level
1 in 25
1 in 15
Coal Face
March
1915

Fig. 7.—"Ventilated" Plan with Conventional Signs.

In particular they should each frequently undertake the cleaning, charging, repairing, and testing of the apparatus. Suggestions for improvements in detail should be encouraged after the system practised at the Northumberland and Durham Stations. Colliery brigades should also be required from time to time to carry out the operations mentioned above. Especially should the captain and vice-captain of a colliery brigade be able to test rescue-apparatus for leakage and for oxygen-supply. An excellent test of a man's should be noted, and attention should be drawn to the insensitiveness of a bird or of a man to even large percentages of firedamp or blackdamp.

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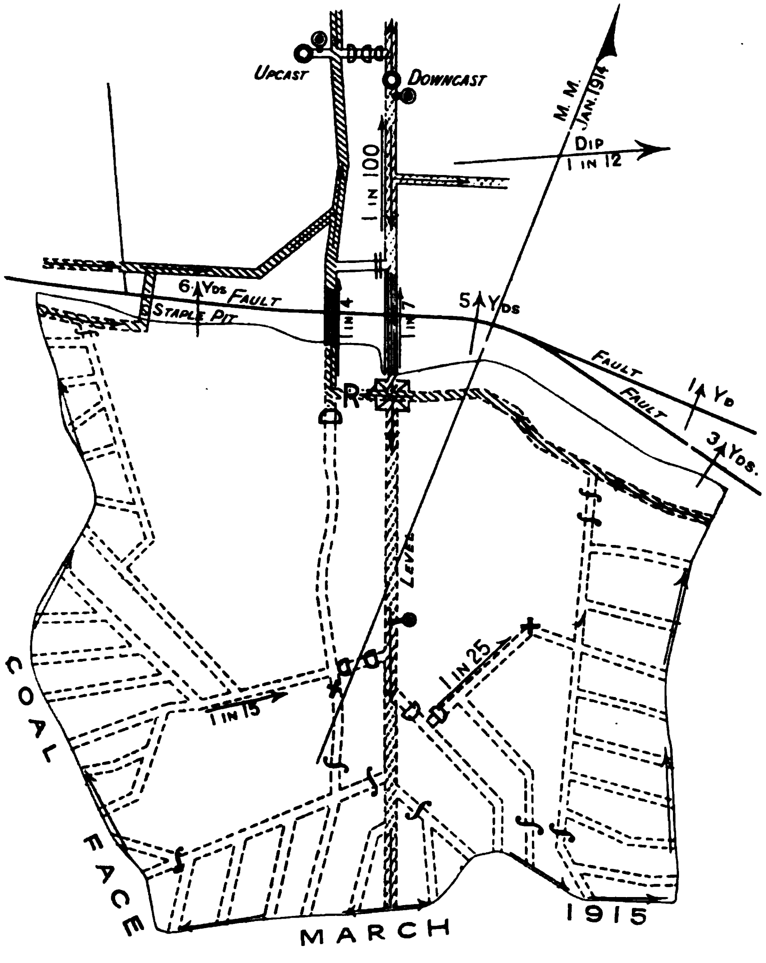

Upcast
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3 Yds.
R
Level
1 in 25
1 in 15
Coal Face
March
1915

Fig. 7.—"Ventilated" Plan with Conventional Signs.

knowledge of the apparatus is to confront him with the apparatus dismantled and the parts mixed in disorder and ask him to put them together.

(*d*) *Rescue- and Recovery-work* (page 41).—Attention is here drawn to instruction in the use of the various appliances used in rescue- and recovery-work. These include, in addition to the smoke-helmet, the various forms of reviving-apparatus and the portable telephone. With regard to revivers, the preference of the Committee at present leans more towards the simplest type than towards the more elaborate, and they think that special attention should be directed to training with the simple form. Instruction should also be given in Schäfer's method of artificial respiration with and without an apparatus for breathing oxygen.

The great practical value of a ready means of communication between those underground engaged in rescue- and recovery-work and those on the surface is pointed out, and the lines on which instruction in telephonic communication should be given are indicated. Methods of effecting communication between those stationed at a fresh-air base and those working on rescue-work in an irrespirable atmosphere are described. From the base to the working party spoken messages may be transmitted by the portable telephone, but communications from the party to the base should be by signal with the bell or buzzer. This arrangement obviates the temptation of removing the mouthpiece in order to talk clearly through the telephone, besides being more definite and more expeditious. In order to prevent misunderstandings, all signals received at the base should be repeated to the transmitter. A uniform code of signals (see Appendix) is recommended for general adoption. In order to provide a ready means of communication between individual members of a rescue-party, a cycle horn or some equivalent contrivance should be carried by every man. The code of signals has been drafted to suit this means of communication as well as the telephone or the electric bell.

(*e*) *Additional Instruction of Captains* (page 43).—The Committee think that captains of brigades should be encouraged to attend more advanced courses of instruction in gas-detection, plan-reading, ambulance, and in the construction, repair, and testing of breathing-apparatus, such as has been followed for several years at Birmingham University. It is further suggested that captains should form themselves into squads of four or five, and at frequent intervals attend the rescue-station to take part in the work of the regular staff. Their knowledge and efficiency would thereby be much improved.

(*f*) *Code of Rules for the Carrying out of Rescue-work* (page 42).—The diversity in the various sets of rules in use throughout the country for the guidance of persons engaged in rescue- or recovery-work is held to be a source of weakness, and a single code (see Appendix) is recommended for adoption at all mines. The code is intended to be suitable for both the resident- and the non-resident brigade systems. The rules relating specifically to the ordinary members of brigades are few, simple, and easily learned. It is not intended to preclude the station managers or superintendents from adding to the general code any other rules considered necessary.

Miscellaneous.—The following matters are also referred to in the Report:—

(1) The Committee consider that the provision of Red Cross rooms at mines should be made compulsory. This room should be situated conveniently near the shaft or outlet, and should contain all requisites for rescue and ambulance purposes (page 43).

(2) The appointment of quartermasters at mines is recommended. Their duties, during recovery-work with rescue-apparatus, would be to see to the refreshment and general comfort of the rescue-teams (page 44).

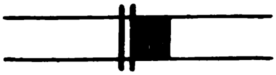
(3) Competitions between rescue-brigades, after the system in vogue in many mining districts in connexion with ambulance teams, would, it is held, stimulate interest in the subject of rescue-training among miners, maintain the zest and efficiency of the members of the brigades, and encourage enlistment for the brigades (page 44).

(4) The institution of annual conferences of rescue-station instructors is advocated. At those meetings, which should be open to mine officials and members of rescue-brigades, opportunities would arise for reading and discussing papers, exchanging experiences, inspecting rescue-stations, and generally keeping in touch with the developments of a rapidly-evolving subject (page 44).

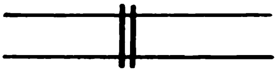
(5) The Committee consider that shale-mines should be included under the regulations respecting rescue-operations (page 45). It is pointed out that, in the case of the Scottish shale-mines, on two occasions in the last two years underground fires have necessitated the calling for the services of rescue-stations and the use of self-contained rescue-apparatus and smoke-helmets. It is also suggested that when any new legislation relating to metalliferous mines is being introduced, the question of applying the rescue regulations to such mines should be taken into consideration (page 45). Two instances are given of iron-ore mines requiring the services of rescue-brigades. On one of these occasions the life of one man gassed by carbon monoxide was saved by the aid of the brigade.

CODE OF VENTILATION SIGNS.

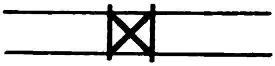
Brick, stone, or concrete stoppings, explosion proof (*General Regulation* 91) ... ...



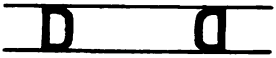
Brick, stone, or concrete stoppings other than the above ... ...



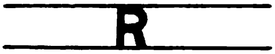
Fire-dams or seals ... ...



Doors ... ...

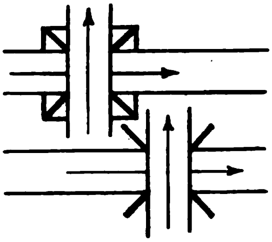


Regulators ... ...

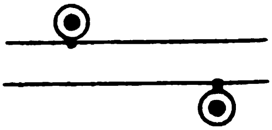


Air-crossings, explosion proof (*Section* 42 (3), *C.M.A.*, 1911) ... ...

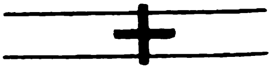
Air-crossings other than the above ... ...



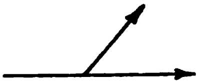
Telephones ... ...



Underground ambulance-station ... .



Direction of air-current ... ...



Intake airways—Blue (shown by medium shading on Fig. 7)

Return airways—Red (shown by close shading on Fig 7)

APPENDIX.—SUGGESTED UNIFORM CODE OF RULES FOR THE CONDUCT AND GUIDANCE OF PERSONS EMPLOYED IN RESCUE-WORK.

MANAGER OR PRINCIPAL OFFICIAL FOR THE TIME BEING AT THE SURFACE OF THE MINE.

(1) On receiving information of any occurrence likely to require the service of rescue-apparatus, the following steps shall be taken by the manager, or, in his absence, by the principal official present at the surface :—

(*a*) Telephone to the central rescue-station. Inform the instructor of the character of the occurrence. State whether assistance will be needed from rescue-brigades other than the permanent station corps or the brigades attached to the mine;

(*b*) Summon the trained men attached to the mine;

(*c*) Telephone for medical assistance;

(*d*) Telephone to the Inspector of Mines;

(*e*) If necessary, communicate with the police-station.

(2) No person shall be allowed to enter the mine or the part of the mine which is unsafe for the purpose of engaging in rescue-operations unless authorized by the manager, or, in his absence, by the principal official of the mine present at the surface; and, during the progress of such operations, a person or persons shall be stationed at the entrance of the mine; and required to keep a written record of all persons entering and leaving the mine. Only men trained with the apparatus shall be permitted to enter the mine for the purpose of using rescue-apparatus.

(3) Prior to sending a brigade underground, clear instructions shall be given to the leader of the brigade as to where it shall go and what it shall attempt. Unless the leader is personally thoroughly familiar with the roadways in question, the route shall be marked on a tracing, which the leader shall take with him into the mine.

(4) A qualified medical man shall be in attendance at the mine wherever rescue-parties are at work, unless in the opinion of the manager and Inspector of Mines that course is unnecessary.

The doctor, when present, shall examine every man engaged in rescue-work before permitting him to go underground for a second spell of that work.

(5) As soon as possible a base or bases shall be established in fresh air, but as near to the irrespirable zone or zones as safety permits. Each such base shall, if possible, be connected by telephone to the surface or to the shaft-bottom. Whenever men are at work beyond the base, there shall be stationed at the base at least the following: (*a*) two men of which at least one should understand rescue-appliances and first aid; (*b*) a spare brigade with rescue-apparatus and ready for immediate service; (*c*) one or more oxygen revivers, stretchers, and birds.

CAPTAIN OR LEADER OF A RESCUE-BRIGADE.

(6) The leader shall not permit the brigade to go underground until he has received clear instructions from the manager or from the person acting on the manager's behalf; and, unless the leader knows the route thoroughly, he shall take underground a plan on which the route is clearly marked.

(7) The leader shall not engage in manual work. He shall give his attention solely to directing the brigade and to maintaining its safety. He shall examine the roof and supports during the outward journey, and, if there is any likelihood of a fall, he shall not proceed until the brigade has made the place secure. He shall not take the brigade through any passage less than 2 feet high and 3 feet wide, except in a case of urgent necessity.

(8) When the atmosphere is clear, the leader shall, when passing the junction of two or more roads, clearly indicate the route by means of arrow marks in chalk. When the atmosphere is thick with smoke, the leader shall see that a life-line is led in from fresh air, and shall not allow any member of the brigade to move out of reach of that line; or, if that course is impracticable, he shall not proceed until every road branching from the route is fenced across the opening.

(9) Before proceeding underground, the leader shall test, or witness the testing of, every rescue-apparatus of the brigade. He shall check the equipment of his party, and, immediately before entering irrespirable air, make sure that every apparatus is working properly.

(10) When using rescue-apparatus the leader (who shall carry a watch) shall read the pressure of the compressed oxygen every 20 minutes, or thereabouts, and shall commence the return journey in ample time. In travelling, he shall adapt the rate to that of the slowest member.

MEMBERS OF RESCUE-BRIGADES.

(11) Members of brigades shall, in general, use the prescribed signals in communicating to one another.

(12) In travelling with rescue-apparatus, each member of the brigade shall keep the place given him when numbering off. If the pace is too quick, or if distress is felt for any reason, the member shall at once sound the distress signal.

(13) No person shall commence a second or subsequent spell of work in bad air without being examined and passed by a doctor, if present, or by the rescue-station instructor or other competent person if the doctor be not present.

CODE OF SIGNALS.

(To be used when working in poisonous air)

Electric signalling.	Signalling between members of a brigade.	Signal.
"Distress" or "Help Wanted.	"Distress" or "Help Wanted"	ONE *prolonged* ring, or a *prolonged succession* of hoots.
(If NO ANSWER is given to a call, "Distress" is to be understood)		
"Not Understood" or "Repeat the Message."	Halt	ONE sharp ring or ONE hoot.
"No"	Retire	TWO sharp rings or TWO hoots.
"Yes" or "All Right" or "All's Well."	Advance	THREE sharp rings or THREE hoots.
To "Ring up." To "Ring off."	To call attention	FOUR sharp rings or FOUR hoots.

The PRESIDENT (Mr. G. Blake Walker): All who are interested in rescue-work will doubtless agree that the Government have done the right thing in taking up this matter. Whether the apparatus they eventually approve will be perfect or not, I do not know; but at present we are rather at variance in regard to the merits and defects of the appliances now being used. With respect to rescue-brigades, many of us suffer from the disadvantage that a number of our trained men have gone to the front, and we have to contend with the fact that as the years roll on our trained men reach the age of 50 or over, beyond which age, according to the Report, it is considered that they ought not to be employed. It is quite evident that men in advanced life are not suitable for rescue-work, and the younger men are very often indisposed to take it up. The whole question is one of considerable difficulty, and it is a pity that the apparatus which we now have installed in the different rescue-stations seems likely to be scrapped. Some fatal accidents have undoubtedly occurred owing to the failure of rescue-apparatus, and we certainly have no wish to provide death-traps for our men. I hope that the result of the investigations of the Committee, which is composed of able and practical men, will provide us with something better than we have at present. Either before or after legislation, we shall have to consider most carefully what to do in the matter, for the alterations foreshadowed in the Report will make a considerable difference in the management of our rescue-stations.

Mr. H. Eustace Mitton (Codnor): I do not see how we can discuss or fully consider the matter until we have the opportunity of seeing the Report itself. I note that the Kent coalfield is entirely omitted from the plan illustrating Mr. Penman's paper. I do not know whether this coalfield does not need any rescue-apparatus, but it is not shown as possessing a station. In looking over the digest, I see that the First Report does not deal with the question of liquid air. When I first had the opportunity of talking with Sir William Garforth about the formation of the Mines Rescue Committee, I told him that I thought one of the points to which it should direct its attention would be to consider very thoroughly the question of oxygen *versus* liquid air. There is a wide difference of opinion on this matter, and I, therefore, do feel that it is one which the Committee might have considered. The question of rescue-work is only in its infancy; we have only just commenced to realize that there are forms of apparatus for which we could find a valuable use in our mines; in various districts large sums of money have been expended upon them; and just as we were beginning to get to work, and the interest of the whole mining industry was being aroused in the work, we were faced with the present war. The result was that men who were trained in rescue-work were taken away, and we were confronted by the difficulty of finding others to take their place. We cannot serve any useful purpose by discussing Mr. Penman's paper now, and I suggest that the discussion be adjourned to some further meeting, as it is certainly one of the most important questions which has been brought before the mining industry of late years.

Mr. G. L. Kerr (Glasgow): I cannot agree with Mr. Mitton that the paper should not be discussed, for the reason that only what has been read to the members of the Institution should be discussed, and not some Report which is not before us. I would also draw the members' attention to the following terms of reference under which this Research Committee was appointed to make enquiry, as quoted by Mr. Penman:—

> "To inquire into the types of breathing apparatus used in coal mines, and by experiment to determine the advantages, limitations, and defects of the several types of apparatus, what improvements in them are possible, whether it is advisable that the types used in mines should be standardised, and to collect evidence bearing on these points."

That is a reference which confers very wide powers on the committee, and would entail a great deal of labour. The points of reference, if fully inquired into, would be of the utmost value to colliery managers and other mining officials who are responsible for the selection and use of the best type of apparatus. The Report appears to limit itself to enumerating the various types of apparatus in use, but there is nothing said about the different types of breathing-apparatus used in coal-mines, nothing about the advantages and limitations of each type, and no opinion offered on the advisability of standardizing the types used in mines. It is possible that these questions, which are of the utmost importance, will be dealt with in a future Report. It will no doubt be an inviduous task for the Research Committee to state all the advantages and limitations of each type, and probably more invidious to state which is *the* best type of apparatus for use in coal-mines. But these are questions which ought to be dealt with, as a colliery manager is hardly able himself to judge which is the best apparatus to use. I have been asked this question repeatedly, but it is an invidious question to ask anyone, and a difficult one to answer. I do not blame Mr. Penman for having said nothing about these questions, as he only set out to give a digest of the Report issued by the Research Committee, and a very interesting digest he has given us; but he is in the difficult position that while he has written this comprehensive digest he is not responsible for any opinions expressed in it, and that makes the difficulty of discussion and criticism all the greater.

Mr. DAVID PENMAN: The First Report mentions that other Reports will be issued subsequently, and only claims to be a "first" Report. As a rule, a first report maps out the ground which is to be covered, and obviously the matter could not finish with the present Report.

Sir WILLIAM GARFORTH (Pontefract): I quite agree that the discussion should be adjourned until we have had the opportunity of considering closely both the paper and the Report. From the experience gained in the last fifteen or twenty years, great advances have been made in regard to the safety of mines; but although in the future explosions may not occur on the same scale as in the past, we do not know whether the introduction of electricity in deep mines may not cause an even greater necessity for rescue-apparatus. Under the heading of "Miscellaneous," it is stated that the Committee suggest that—

> "Competitions between rescue-brigades, after the system in vogue in many mining districts in connexion with ambulance teams, would, it is held, stimulate interest in the subject of rescue-training among miners, maintain the zest and efficiency of the members of the brigades, and encourage enlistment for the brigades."

I think that if we could have friendly competitions among the men in the way mentioned, and have demonstrated, in a competitive fashion, the merits of the various kinds of apparatus, it is very likely that in a year or two the best points in each apparatus might be embodied in one, which might be called the "British" apparatus, and go forth as such apparatus to managers, engineers, and workmen in every part of the world. I know well how such competitions have helped us in ambulance work, and more recently how the holders of garden allotments, which have been introduced into most of our mining villages, have been considerably stimulated by friendly rivalry. I believe that we should make a great step forward in improving our rescue-apparatus if we could secure the co-operation of the workmen. The hope of reward sweetens labour, and whether it comes in the form of a pat on the back or of something more substantial, there is no doubt that it has a beneficial effect. I think that a shield might be the means of helping forward rescue-work in the same way that ambulance work has been promoted, and I should be glad to give a hundred or a hundred and fifty guineas for the provision of a shield to be competed for. It should be called "The Shield of The Institution of Mining Engineers," in order that everyone may realize, as most people have done in the past, that coal-owners have done, and are now doing, all that they can to promote the safety of their men, acting on the motto: "Safety first and profit afterwards." There ought to be no difficulty in carrying out the suggestion of the Committee so far as friendly competitions are concerned.

Mr. J. Parkinson (Barnsley): With regard to a competition, while I agree it might stimulate rescue-work in the sense of encouraging the men to join rescue-teams, I do not think that it would prove which is the best rescue-apparatus on the market. I believe that the men would join up, not for the reward they would get, but from the competitive spirit which has proved so successful in ambulance work. I would confine the competition to colliery brigade-men who work underground, and not to the permanent staff, who are more of the character of instructors or assistants. The younger men are certainly rather dubious about the matter at present. They see the reports in the newspapers and comments on the different types of apparatus; but if we turn to the First Report of the Research Committee, we find that no remedy is suggested—they do not put forward a standard type.

Mr. E. W. Thirkell (Wakefield): Mr. Penman's digest of the Report serves merely to draw our attention to the principal points in the Report, and no rescue-station or those in control of a rescue-station ought to be without the Report itself. We are not here to discuss the merits or demerits of any particular type of apparatus, but to discuss the Report and see what arises out of it. Certain defects in various kinds of apparatus have been mentioned, and it will be for those who have to use any of these types to see whether they can put these defects right themselves. A great deal can be done at the rescue-stations in finding out where the faults are, and probably in many cases the remedy for them will be discovered. This, in fact, is being done at the Wakefield and Rotherham rescue-stations. I should like to express our thanks to Sir William Garforth for his very generous offer, for I certainly think that a competition amongst rescue-teams will do good. I do not regard it so much as a means of securing the best type of apparatus, but such a competition cannot fail to have useful results.

Mr. JOSEPH PARKER (Cowdenbeath) wrote: Mr. Penman's digest shows the Report to be characterized by strong common sense, which goes very far to disarm destructive criticism. There will be general agreement with the statement that "unless the apparatus worn provides a fair margin of security during the period of greatest demand, it cannot be considered adequate or safe." It is noted that, as an absorbent of carbon dioxide, caustic soda is less active when cold than when it has been warmed slightly. But since, in practice, the caustic soda will tend to be uncomfortably hot rather than cold, a point of great interest would be to ascertain whether the temperature of maximum activity of the absorbent may not be very liable to be greatly exceeded when the apparatus is in use; and, if so, what are the most efficient methods of maintaining the caustic soda at a temperature as nearly equal to that corresponding to maximum activity as possible. Doubtless the Committee in a subsequent report will have much of interest to say on this point. The suggestion for the frequent testing of pressure-gauges is good; and the appliance shown for testing gauges is both simple and effective. The proposal as to the method of operation of the main valve of the oxygen cylinder and the sunk-spindle valve and key are also very good. The figures given in the table showing the consumption of oxygen in climbing various gradients are very instructive, and appear to indicate that the minimum supply of oxygen should be about 1½ litres per minute, but that this should be capable of being increased to double that amount when occasion demands. The method of getting rid of as much nitrogen as possible from the bag and from the lungs, so that the wearer may start on practically pure oxygen, is the best practice, and has been that followed for some considerable time at some rescue training-stations. The reason for the provision of a bye-pass and for the use of the single oxygen cylinder appears obvious. That the oxygen should be analysed before being used is evident from the analyses given. The face-mask has so many decided advantages that it might be permissible to enquire whether sufficient efforts have been made to perfect it before definitely casting it aside. With regard to the risk of "premature action" of the automatic relief-valve, it is always a very delicate matter to arrange that an automatic relief-valve shall act with a small rise of pressure in the breathing-bag, and not act prematurely. This points to the necessity for a more perfect regulation of the oxygen supply, so as to render it unnecessary that the relief-valve should act very frequently; and if this could be secured, the objection to opening the relief-valve by the hand would be practically removed, and the automatic relief-valve would then be discarded.

Mr. A. T. Winborn (Crumlin, Mon.) wrote: The recommendations of the Committee appear to be somewhat sweeping. It is certain that no single form of apparatus embodies all the good points recommended; and it is almost equally certain that even the Research Committee themselves would be quite unable to construct a complete breathing-apparatus embodying all these good points. When one considers the problem of temperature of the inspired air and the probability of further recommendations under this head, the task of rescue-apparatus construction from existing types is likely to become still more hopeless. The Research Committee have carried out an extremely valuable piece of work, and their recommendations, when acted upon, cannot fail to result in the evolution of a breathing-apparatus that will tend to reduce the risk of accident. It is doubtful whether the recommendations suggested by the Research Committee will be endorsed *en bloc* by station superintendents throughout the country. There are still a number of thoroughly experienced men who believe in the "injector" class of apparatus. Some of these can point to long records of practical work performed underground, immune from accident, and their faith in an apparatus which they have worn at the risk of their life is not easily shaken by theories advanced by men who sometimes lack practical experience. These men have their own theories as to the cause of accidents that have happened in the past, and they do not in every case attribute this to failure of the apparatus, but to failure of the human element. Space does not permit to discuss the recommendations regarding constructional details. Some items have to be regarded from more than one view-point. An emergency-valve or "bye-pass," for instance, is apparently an advantage, but a close investigation shows that this is not always the case. Emergency valves are at times liable to injudicious use, and one guard against this abuse lies in the provision of fixed relief-valves to breathing bags, for the reason that the use of the valve is immediately accompanied or followed by a distension of the breathing-bags, which reminds the wearer of what he is doing. In the case of automatic any of these types to see whether they can put these defects right themselves. A great deal can be done at the rescue-stations in finding out where the faults are, and probably in many cases the remedy for them will be discovered. This, in fact, is being done at the Wakefield and Rotherham rescue-stations. I should like to express our thanks to Sir William Garforth for his very generous offer, for I certainly think that a competition amongst rescue-teams will do good. I do not regard it so much as a means of securing the best type of apparatus, but such a competition cannot fail to have useful results.

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It is possible for a two-hour supply of oxygen to escape through an emergency-valve in two minutes, and the use of this valve, even for a few seconds, means a sensible reduction in the two-hour " life " of an apparatus. The danger attached to the injudicious use of these valves is obvious, particularly if a man resorts to it on the return journey when in-bye. It must not be concluded that the writer is prejudiced against emergency-valves; his remarks are made with the object of showing that some of the recommendations contained in the Report are debatable. The statement regarding the necessary number of brigade practices appears to be somewhat ambiguous, and more definite recommendation as to the number of practices necessary for efficiency would have been more satisfactory. As the clause stands, it will be taken to mean that four practices a year are sufficient. How many experienced men really believe this? It is no uncommon experience for a superintendent to have to explain over again the different parts of an apparatus to men attending for their quarterly practices. With each succeeding quarterly practice the average man becomes less intimate with his apparatus, and when questioned a man does not as a rule hesitate to ask: " How can you expect us to retain all we have been taught in our initial course?" They will also say: " As soon as we leave the station after a quarterly practice we hardly ever *think* of an apparatus, and never *see* one until the next quarterly practice comes round! " Members of rescue-brigades themselves do not consider this number of practices adequate, and it is to their everlasting credit that they come forward readily when their services are needed for real work underground, realizing as they do that they are not so conversant with their apparatus as they ought and would like to be. Pit practice is another question that may be studied from more than one point of view. It is to be presumed that such practices are to be carried out under ordinary normal atmospheric conditions, for it is certain that no colliery manager would consent to the fouling of any part of his mine for rescue-brigade pit practices. The value of such practices is questionable. So long as a man can be trusted to wear his apparatus honestly, pit practices have an obvious value: but unless he does so, there is the danger of establishing false records which upon any occasion of real work might lead men astray. It is a fairly general opinion that practice in wearing rescue-apparatus is of very little value unless carried out in noxious atmospheres, and the policy of substituting two pit practices under normal conditions for an equal number of station practices under irrespirable conditions is of doubtful value. Incidentally, it also reduces the number of real practices from four to two per annum. The writer of these notes is of opinion that efficiency maintenance practices should not be less than eight per annum, and, further, they should in each case be carried out under irrespirable atmospheric conditions.

Mr. David Stevenson (Cowdenbeath) wrote: I would suggest, in connexion with plan reading, that (as required by Regulation 142 (*b*)) duplicates of the actual rescue tracings of all the collieries covered by a central rescue-station should be sent to that station for instructional purposes—and kept up to date in the same way as the originals. These plans should be made as simple as possible, and be marked with all the suggested signs, the dips, and the inclinations, the latter to enable the captain to arrange the speed of the brigade to correspond with the conditions. The members of the brigades should be instructed on these plans at the mine practices, and actual work should be carried out with them. The men would thus learn and work with plans of the collieries in which they would be required to work, if their services with the apparatus should be required. In order to illustrate a case, I will assume two collieries, A and B. The colliery brigade from A colliery attends at the station for practice, and as part of that practice they receive instructions on the plans of a seam in B colliery. Their next practice is a mine practice, and arrangements should be made between the manager of B colliery and the superintendent that a practice with a brigade of A colliery is to take place on a certain date; it should also be arranged that the practice shall be, say, from the pit-bottom to a certain place indicated on the plan, that something (a hammer, for example) shall be left at this point, and that the brigade shall receive instructions to bring this back. On the road to the above point, chalk-marks representing a body, a cap, a lamp, or an overturned tub, could be made on the roof or sides. The idea is to make the members of the brigade observant and give them an opportunity of measuring distances and marking them on the plan.

In order to measure the road, a line of a known length should be used—say, 33 feet—with a hook at each end, the one end to be hooked to No. 1 apparatus and the other end to No. 5. No. 1 would make a mark when he went to the length of the line, and then go on; No. 5 would signal on coming to the mark; whilst the captain would take notes. The above line would serve a double purpose: (1) it could be used for measuring the road, and

(2) whilst in use it would be impossible for No. 5 to fall out without notice, as could easily happen unless such a precaution were taken.

With regard to Rule 7 in the suggested uniform code of rules, seeing that the captain has to keep a look-out on the whole of his men, I am of the opinion that his best place is No. 2 of the brigade. No. 1 should be a man who has been proved to be cool in emergency, who is thoroughly experienced, and in whom the captain could place every reliance. This man should go in front and act as scout to the party, and be able to report to the captain any likelihood of danger. The captain would then have more freedom in fulfilling his already numerous duties.

With respect to the proposed code of signals, one prolonged ring is to be given in a case where help is wanted; one sharp ring is also to be given in a case of misunderstanding. In my opinion there should be no interference whatever with the distress signal, and I think that the arrangement should be that one ring, whether short or long, should be the signal of distress and not be confused with any other signal.

Mr. ROBERT CURRIE (Crumlin, Mon.) wrote: In view of the fact that the average superintendent of a rescue-station is guided largely by such experts as the Commissioners, it is to be regretted that some of the recommendations have not been examined more in detail by Mr. Penman. The great importance of the purity of the oxygen for the breathing-apparatus is duly noted by the author, and it is suggested that a suitable method of analysis can be carried out by an apparatus designed by Dr. Briggs, a member of the Commission. The writer of the present note has not seen the Report as issued by the Committee, but takes it for granted that the apparatus referred to is similar to that made by Messrs. Baird and Tatlock to the specifications of Dr. Briggs, a description of which was sent to the rescue-stations a few months ago. This particular apparatus cannot possibly be of any service to the rescue-station, and may in some cases prove a grave danger. The circular conveys the impression that the apparatus will demonstrate the purity of the oxygen supplied, but this is not the case. It contains only one absorbent solution, namely, pyrogallic acid in a caustic-potash solution. It is a well-known fact that this solution will absorb both carbon dioxide and oxygen; hence any of the former gas present in the sample will be regarded as oxygen. The residual gas, according to the circular, is evidently to be taken as nitrogen; but, according to the Committee's Report, this may contain an inflammable gas in the form of hydrogen. The writer would ask Mr. Penman to investigate this point, and inform the members of the Institute whether he could determine with the aid of the apparatus the difference between two samples, A and B, if A contained 99 per cent. of oxygen and 1 per cent. of nitrogen, and B contained 99 per cent. of carbon dioxide and 1 per cent. of hydrogen.

Mr. **Walter Clifford** (Mines-rescue Station, Stoke-on-Trent) wrote: I do not consider that rust in the Proto apparatus is so much a danger as an inconvenience and expense, as the gauze under the reducing-valve appears to prevent effectively the rust from getting into the valve; but nevertheless the formation of rust should be prevented if possible. The first time I discovered rust was during the recovery work at Norton Colliery in 1912. The cylinders were pumped up some little time before they were used, and when needed one of them was found to contain a pressure of only about 75 atmospheres. I was inclined at first to accuse the man in charge of the pump of carelessness, but as the same thing happened the next time the apparatus was used, I suspected a leakage. Immersion in water failed to show any outward leakage, and I therefore concluded that the tube connecting the two cylinders must be partly blocked by rust. I filled the twin cylinders at the pump, and noticed that they filled up quicker than usual. I turned off the valves, allowed the apparatus to stand, and after perhaps half an hour again tested the pressure, which had then dropped to 100 atmospheres. It continued to fall slowly until it reached about 70, which proved that the pressure was being gradually equalized in the two cylinders. Since then I have had several occurrences of a similar kind. In a sense, the partial choking of the connecting-tube is a danger, as the cylinders may be pumped up until the gauge shows a pressure of 2,000 pounds (on the pump), but even then there would not be a two-hours' supply of oxygen. A great deal depends on the intelligence and experience of the man working the pump. An experienced man knows to a nicety the rate at which cylinders fill, and if the gauge-fingers should move more rapidly than usual, he would at once suspect rust trouble.

I have found rust accumulates also in the arm from the cylinders to the main valve. I make a practice from time to time of poking a steel wire through the valve as far as it will go up the tube in order to remove the rust. One one occasion I dislodged as much as half a thimble-full of rust from this tube alone. Although I have never had a case where the oxygen supply has been completely cut off by rust, I am sure that there is a danger of this happening.

I cannot say that I am in favour of fitting a single cylinder to the Proto apparatus, as I think this would make it clumsy and ill-balanced. The connecting-tube might with advantage be made larger. There is no doubt that a lot of the rust is caused by water, in the form of spray, entering the cylinders from the pump. Even with the utmost care in using the pump, it is impossible at times to prevent spray from passing into the cylinders. If dry oxygen could be used, much less rust would be formed.

With regard to the establishment of three men on the staff of a rescue-station with 50 or more brigades, I am particularly pleased to see this recommendation. My own opinion is that all three should be *skilled* instructors—that is, able to assume control of the station if necessary. When only two are employed, it is impossible, compatible with complete efficiency, for either of them to take even a few hours a week off duty, as when anything serious occurs one instructor cannot do all the work which suddenly falls upon him. For instance, at the fire at Hem Heath Colliery I worked continuously from Thursday morning to 5 p.m. on Saturday evening. At Norton I and my assistant worked 70 hours without a break, and then rested for a few hours, the apparatus being put in charge of an engineer; we then received a message to the effect that the men refused to descend unless I returned to attend to the apparatus. At Silverdale Colliery my assistant worked from Thursday afternoon to Sunday night without a stop on the occasion of the bricking-up of a gob-fire. These are a few instances of unavoidable long-continued spells; but if the station had possessed a bigger staff, the work could have been divided. The mental strain, apart from the physical exertion, is very great on such occasions, and I feel that the apparatus would be better looked after if the work could be divided into regular shifts, so that each instructor could take 8-hour shifts, and each be assisted by an intelligent man with some experience of the apparatus.

Mr. David Penman, in reply, said: I think you will find my paper is a true digest of the Report, but I fully agree with those speakers who have urged that the discussion should be left over until an opportunity has been given of studying the Report itself. There are a great number of matters referred to in it which require discussion, and the work of the Research Committee would be strengthened by bringing forward the vast amount of experience which otherwise might not be obtained.

Mr. D. Penman subsequently wrote: I am sure that the Research Committee will feel indebted to all who have taken part in the discussion. The valuable comments of some of the members will undoubtedly aid the Committee greatly in their investigations. I have no doubt that many of the points raised so far will be investigated, and I would like other members to give the Committee the benefit of their experience of apparatus and of rescue-work.

With regard to the omission of any recommendation as to which is at present the best form of apparatus, it will be evident from the discussion that the Committee adopted the correct attitude in not specially praising in their First Report any form of existing apparatus. If the recommendations of the Committee, however, are put into practice for each individual form of apparatus, there can be no doubt that improvement will result. Research of the kind, to be effective and satisfactory, must be exhaustive and complete: and at the present stage it is inadvisable, and indeed impossible, to indicate the final form of the apparatus. The aim of the Committee was correctly expressed by Sir William Garforth, when he said that the research would probably result in the evolution of an improved form of apparatus. The Research Committee and the members in general are undoubtedly grateful to Sir William for his kind and generous offer of a shield to be competed for by rescue-brigades from all parts of the country. I take this opportunity to express my thanks to him for his handsome offer, and I am sure that the Committee will also appreciate it.

The difficulty of the age-limit for members of brigades is due largely to the exigencies of the war. The question of oxygen *versus* liquid-air apparatus is closely engaging the attention of the Committee, and an exhaustive enquiry is being conducted into the relative merits of the two types. So far as I know, there is no central rescue-station in the Kent Coalfield. The effect of temperature on the absorbent power of caustic soda is being actively investigated at the moment. Respecting the face-mask, I would point out that the Committee only propose the abolition of existing types. They would be the last to stand in the way of future improvement.

The whole question of the merits and demerits of the emergency-valve or bye-pass depends upon the degree of training of the men wearing the apparatus. If a man has been thoroughly trained in the use of the apparatus, there is no reason why the bye-pass should be misused. The Committee consider that the advantages attached to its use outweigh the disadvantages, and that the latter can be practically eliminated by careful training.

The Committee are strongly of opinion that practice trainings can with advantage be carried out with greater frequency than four times a year, and if Mr. Winborn can see his way to induce his men to put in eight practices per annum, I am sure the Committee will be gratified. The difficulty of fouling the atmosphere in underground practices is not insuperable. During a recent quarterly practice in the Edinburgh neighbourhood the fouling of the atmosphere for training purposes was carried out quite successfully. An abandoned road, not far from the shaft-bottom, and conveniently near the return airway was chosen. An irrespirable atmosphere was created by the burning of gelignite, oily waste, and sulphur. A current of air was so directed that the fumes travelled along the road directly into the return airway and to the upcast shaft. The work was carried out under the supervision of Mr. J. Cooper, Instructor at the Edinburgh Station, and with the cordial co-operation of Mr. R. Durie, of the colliery staff.

The suggestions made regarding practice in plan-reading for colliery brigades should prove helpful for rescue-station instructors. The particular order of the members of brigades and the question of signals to be adopted are matters that must be decided by experience.

Mr. Currie directly attacked the analysis apparatus designed by Dr. Briggs, and stated that it "cannot possibly be of any service to the rescue-station, and may in some cases prove a grave danger." The fact that the apparatus is in daily use at several rescue-stations where its utility has been proved by actual service is a sufficient refutation of this charge. Incidentally, it may be added that the apparatus is being used for a special War Office purpose for carbon-dioxide analysis where results have to be obtained with great rapidity. Mr. Currie asked me whether, by means of the apparatus, I could distinguish between two samples, labelled "A" and "B," one containing oxygen and nitrogen, and the other carbon dioxide and hydrogen. It would obviously not be possible with the apparatus in question to distinguish between the two samples. But why ignore what every instructor knows, namely, the source of the samples? Oxygen manufactured by the liquefaction process could not contain hydrogen. It is only when the gas comes from Birkenhead or Wolverhampton, where the electrolytic process is used, that hydrogen is to be feared. In the latter instance, as the Report states, the analysis apparatus should be capable of determining the amount of hydrogen as well as the total impurity. Neither of the designers of the two forms of oxygen analysis apparatus described in the Report considered it necessary to provide for the elimination of carbon dioxide before testing for oxygen. From their knowledge of the process of manufacture of oxygen they knew that carbon dioxide, if present at all, occurred in negligibly small proportion. They were thus able to devise simpler appliances.

The choking of the connecting tubes of oxygen cylinders by rust has been met with at some time or other by most rescue-station instructors. The single cylinder, by obviating the necessity for a narrow-bore connecting tube, is to be preferred to the double cylinder. A device which will ensure dry oxygen being pumped into the cylinders will undoubtedly retard the formation of rust.

THE CHANCE ACETYLENE SAFETY-LAMP.

By WILLIAM MAURICE, F.G.S., M.I.E.E.

In June, 1917, I submitted some notes on acetylene mine lamps,* and in the course of the subsequent discussion the desire was generally expressed that something should have been said concerning the present position of the acetylene safety-lamp. It was not, however, then practicable to describe anything new, as experiments and manufacture had been delayed, owing to the war. The lamp now described presents many interesting features, and although it is not claimed to have reached the final form for regular mine service, it marks distinct progress.

It would seem that if a lamp can be designed that will give a much better light than any lamp now in use, and be as safe as other flame-lamps, the prime cost and maintenance charges being low, it would merit the close attention of the mining industry.

Safety being assumed, the whole question of new lamps turns on the amount of extra light they will give. It is therefore essential that a more satisfactory basis of comparison should be adopted. Comparisons in terms of candle-power convey next to no information, for of two lamps giving the same photometric candle-power one may be immeasurably superior to the other in practical use.

Candle-power tests are nearly always made under laboratory conditions, whereas in practice the illuminating value of any pit-lamp follows a descending curve, which is more rapid in the mine than that due to the inherent defects of the lamp, so that at the end of a shift the value may be only half or a quarter of that with which it started. The new unit of luminous flux, the "lumen,"† will enable more satisfactory comparisons to be

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*[*Trans. Inst. M.E.*, 1916-1917, vol. liii., page 227.

†The lumen has been defined by Mr. F. W. Willcox as follows:—"The lumen is strictly defined as the unit of luminous flux, and luminous flux is radiant power evaluated according to its visibility, that is, its capacity to produce the sensation of light. The lumen is the unit of the quantity of light flowing from a luminous source. The value established for the lumen is the amount of light from a unit source falling upon a unit surface, all points of which are at a unit distance from the source.

"Assume a source of one spherical English candle, and place this at the centre of a sphere of one foot radius. It follows that the lumen is the amount of light which is falling upon one square foot of surface of this sphere. The total area of a sphere with one foot radius is 12·57 square feet. As each square foot represents a value of one lumen, there will be 12·57 lumens on the total sphere. It follows from this that the lighting value in lumens of any luminous source is obtained by multiplying the mean spherical candle-power of the source by 12·57."

made, but no results can be of much value unless they are determined under working conditions and curves are shown for each hour of the shift.

There has not yet arisen an opportunity to determine the lighting value of the Chance lamp in lumens, but as a general indication some figures have been calculated on the assumption that oil safety-lamps will range between 0·3 and 0·8 candle-power, averaging 0·6, and that electric lamps will give about 0·5 mean spherical candle-power and about 1·2 candle-power across the path of light thrown by the reflector, this path subtending an angle of about 130 degrees. On this basis oil-lamps will average 7·5, electric lamps 10·7, and the new Chance lamp 37·7 lumens, or about five times the illuminating value of the average oil-lamp and three-and-a-half times that of the average electric lamp. This increased lighting value will enable the miner to perform his work under conditions of greater efficiency, will tend to reduce —or, at any rate, to make more inexcusable—the filling of dirt, and will undoubtedly lessen the risk of all those accidents which, more or less directly, are the result of ineffective lighting.

A satisfactory acetylene safety-lamp should possess the following qualities:—

(1) Be strong, and so constructed as to withstand considerable rough handling without injury or deformation.

(2) Be simple as to closing and operation.

(3) Be compact in shape, without any projecting parts liable to damage.

(4) Be reasonably light in weight.

(5) Give a better light than any alternative type of lamp.

(6) Be so designed that it can be inclined or even laid on its side for a few moments, without going out or without causing excessive production of gas.

(7) Be self-regulating, so that, once lit, the regulation of the flame does not require attention.

(8) Be convenient in use, well balanced, fitted with suitable handle or hook, and, preferably, about the same weight and dimensions of lamps ordinarily in use.

(9) Be capable of detecting inflammable gas and deficiency of oxygen, and, generally, comply with the usual official tests for safety-lamps.

(10) It should generate gas evenly under all ordinary working conditions.

(11) It should not be a source of danger in itself, either by liberation of a dangerous volume of unconsumed acetylene or by forcing methane ignitions through the gauze.

(12) Cost of maintenance should lie within reasonable limits, having due regard to the fact that effective lighting is a source of profit both to owners and miners.

The Chance acetylene-lamp, which is a combination of the American type of Wolf lamp with the Mueseler principle, adapted to burn acetylene by means of several ingenious advances on earlier practice, can be used to detect the presence of fire-damp in the mine air and to indicate deficiency of oxygen. As already seen, it gives considerably increased illumination. It is, moreover, provided with a special roof reflector (Fig. 9), which furnishes sufficient illumination of the roof without tilting the lamp, and allows a proper examination to be made.

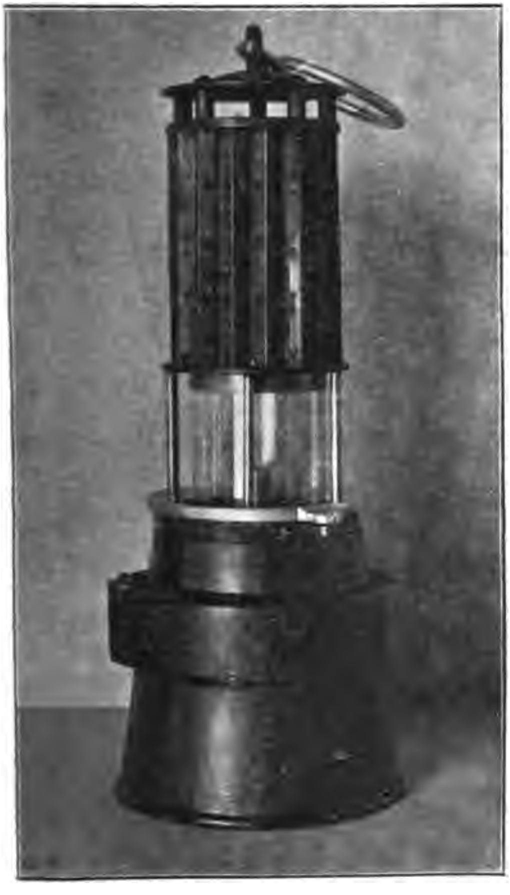

Fig. 1.—Double-glass Reigniting-burner Type of Chance Acetylene Safety-lamp.

Accidents from falls of roof are probably more often related to inadequate inspection than is generally recognized. Any advantage gained in this direction may thus reasonably be set against the more remote possibilities of gas-ignition, which apply to all flame safety-lamps.

Other desirable qualities possessed by this lamp will be easier to recognize after an account of its construction and mode of operation has been given. The complete lamp, assembled ready for use, is shown in Fig. 1; Figs. 2 to 8 show the parts of the same lamp disassembled; whilst Fig. 9 is a sectional elevation of the lamp. The upper part, as will be seen from the figures, follows the construction of the ordinary Wolf-Mueseler lamp, with corrugated shield, double gauzes, and Mueseler chimney. The latter has the usual horizontal gauze at the base and protecting disc at the upper end of the cone. The novelties are in the design of the generator and in the use of a special form of burner.

Hitherto, the only acetylene-lamps which have come into

FIGS. 2 TO 8.—DOUBLE-GLASS REIGNITING-BURNER TYPE OF CHANCE ACETYLENE SAFETY-LAMP.

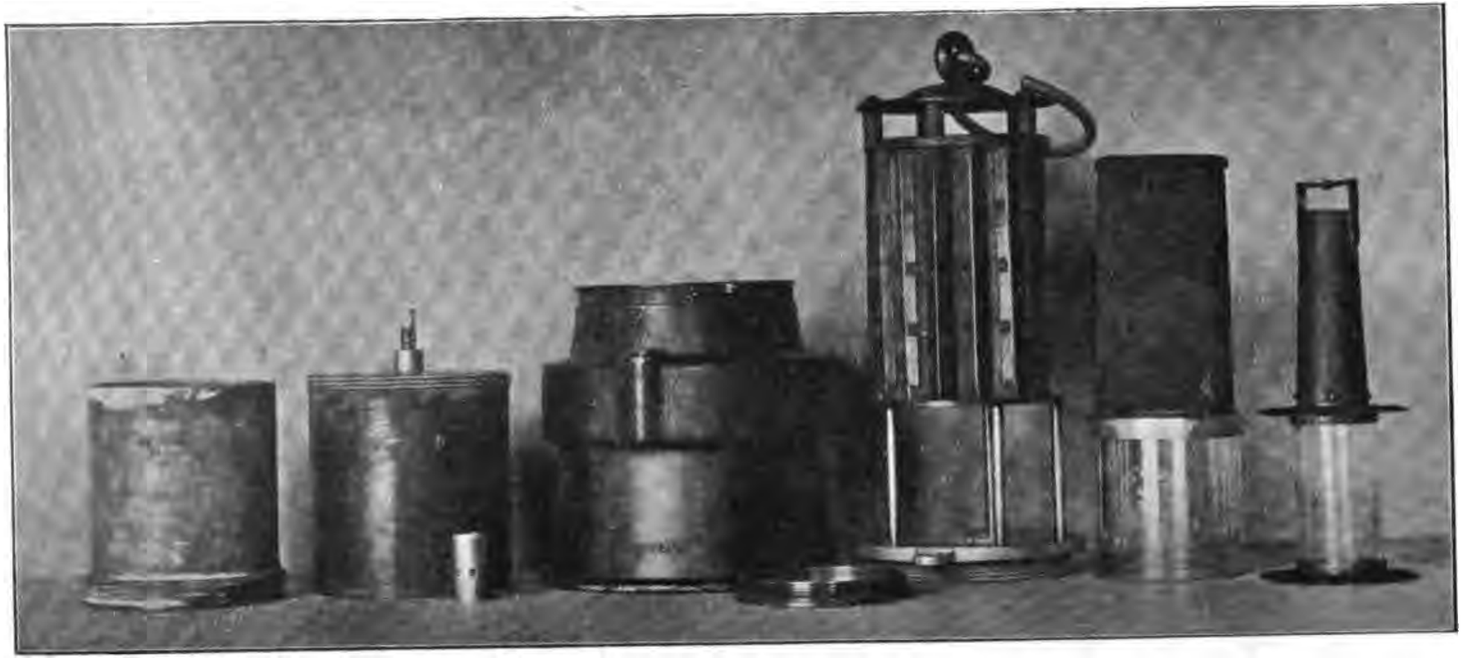

FIG. 2.—CARBIDE-CONTAINER.

FIG. 3.—CARBIDE-CONTAINER COVER, WITH BURNER AND (SEPARATELY) BURNER-PROTECTING TUBE.

FIG. 4.—WATER-VESSEL.

FIG. 5.—LAMP-GLASS RING.

FIG. 6.—LAMP-TOP

FIG. 7.—OUTER GLASS AND GAUZES.

FIG. 8.—INNER GLASS MUESELER CHIMNEY, AND BOTTOM AND MIDDLE HORIZONTAL GAUZES.

general use have been Wolf lamps or designs based upon these models. The last to be developed, so far as is known, was the Wiede lamp, which itself possessed many points of interest, the chief of which was the provision of a cooler for reducing the temperature of the products of combustion. In all these, however, the mode of producing gas was by the use of superimposed vessels, the upper one dropping water slowly into the lower one, which contained the carbide.

In the present model the " contact " system has been adopted, with some interesting modifications. In the " contact " system a vessel containing carbide (closed at the top, save for the gas-exit, and closed at the bottom, except that provision is made for the slow percolation of water through it) is immersed in water. Owing to the pressure due to head, the water enters the carbide chamber and thus generates gas. When working, the gas-pressure inside the carbide-chamber controls the admission of the water, more or less water being admitted as the gas-pressure falls or rises. In Fig. 9 the outer shell *A* (made of cast-aluminium alloy) forms the water-vessel. The carbide-container consists of the inner cylinders *B*, *B′*, the cover *B* being screwed into the water-vessel from above. Cylinder *B* is open at the bottom, which is screwed to fit cylinder *B′*, the latter forming the carbide-holder proper. Concentric with these vessels there is a gas-regulating valve *C*, operated by the hand-screw *D*, situated in the base of the lamp. This valve arrangement permits of raking of the carbide by movement of the valve-stem *C′* acting through the water-feed tube *E* at the base of the container. This has been found to be of great use in preventing stoppage of the water-feed. The water attacks the carbide from below, in the manner already explained, and by this means many of the difficulties of drip generation are overcome. The enlargement of the water-vessel near its middle, as shown in *A′* in Fig. 9, is for the purpose of securing a more uniform head during the working of the lamp.

The spring mechanism *F*, on the left of the illustration, is a water filling-valve similar to the spring filling-valve commonly used on oil safety-lamps. The gas generated by the upward percolation of water through the annular space between the stem *C′* and the tube *E* passes through the upper layers of carbide, filters through the felt pad *D″*, and into the burner-tube *I* by way of the side hole *G* in the valve-tube. The valve serves to shut off gas or to lower the flame for methane-testing. There is no water-valve, the gas-control being automatic. When the valve is partly closed, the gas-pressure increases, thereby pushing back the water into the outer vessel. If the gas-pressure is not sufficiently relieved in this way, water is forced out of the lamp by way of the overflow tubes, of which there are two. One of these is shown at *J* in Fig. 9.

It may happen, if the gas-pressure is greater than can be counterbalanced by the head of water, or than can be relieved by the overflows, that gas itself will escape by the same means. The orifices have therefore been made to lead into the open air downwards, so that any gas which may be discharged will be delivered as far from the air-inlet (which is above the glasses) as practicable. In use, it has been found that the lamp practically never over-generates. Even if it did, it appears to be impossible for such a volume of acetylene-gas to escape into the mine air as would form either an explosive mixture in itself, or be the means of bringing a methane-air mixture which was below the lower limit of explosibility up to danger-point. The brass tube D''' shown surrounding the valve-stem C, and resting on the enlargement C' at the base of this stem, is intended to prevent carbide from falling into the water feed-tube when the lamp is being charged. During charging this brass tube slips down into the water-feed tube E, and is lifted therefrom by the enlargement C' on the valve-stem

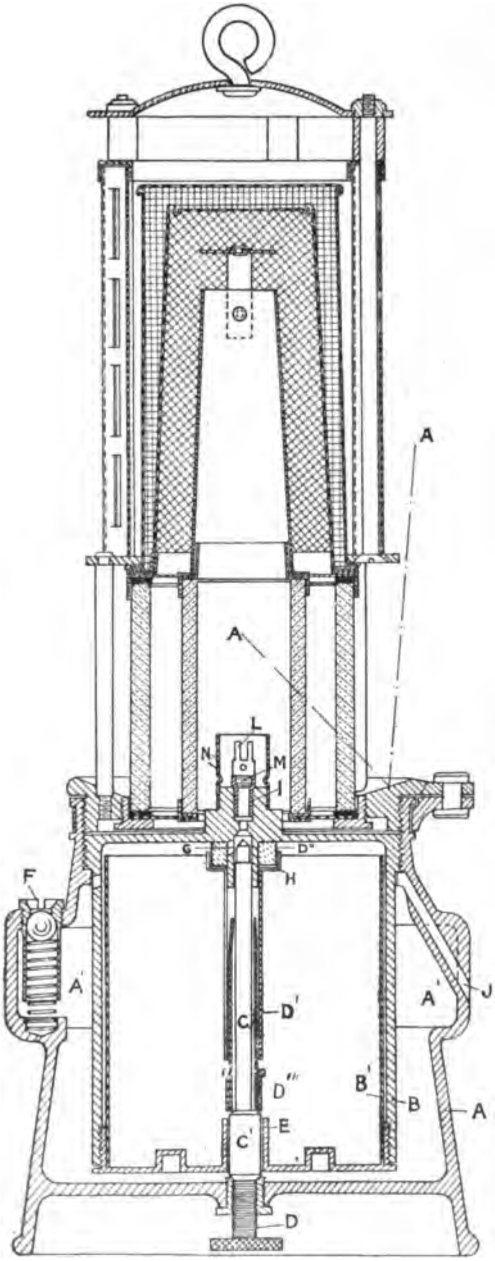

FIG. 9.—SECTION OF DOUBLE-GLASS TYPE OF CHANCE ACETYLENE SAFETY-LAMP. LINE A-A INDICATES LINE OF RAYS REFLECTED TO ROOF.

to the position shown in Fig. 9, when the carbide-container is assembled in the water-vessel. It will be observed that the lamp is not dependent for safety on the presence of a rubber or fibre washer at any point. The gas is water-sealed, with the addition of the mechanical seal formed by the screw-thread at the upper end of the carbide-container. It is believed that this is the first acetylene-lamp in which washers are not used. The washer between the carbide-container and the reflector-ring is merely a mechanical cushion, and has nothing to do with the effectiveness or safety of the lamp.

A considerable objection to the use of acetylene-lamps in the past has been that they may, owing to a little inattention, to concussion due to shot-firing, or to air-pressure resulting from the sudden closing of ventilation-doors, go out. The risk then arises of lamps continuing to generate acetylene which is not consumed and which escapes into the mine air.*

On the Continent of Europe, in all the Colonies, and in most of the mining areas of the United States of America, the Wolf internal igniter is used to reignite flame safety-lamps. In Great Britain the electrical method of relighting is the only permissible one. The Chance lamp has a specially-designed automatic reigniting burner *L* (Fig. 9), which does not appear to present any of the disadvantages of other means of relighting. Advantage is taken of the low temperature at which acetylene ignites, and the Chance burner is so constructed that a temperature sufficient to ignite the gas is maintained—partly in the burner itself, and partly in the burner-protecting shield *N* (Fig. 9).

The Chance lamp combines the use of the Mueseler chimney with that of the double-glass safety-lamp, and is thus practically two safety-lamps in one. If the outer glass be broken, the lamp-flame is still protected, and cannot cause ignition of the outer air.

The inner-glass chimney is virtually spring-supported, so that falls or blows which might break the outer glass have little or no effect on the inner one. The objection to the use of double glasses in ordinary flame-lamps—that the inner glass is liable to become smoked—does not apply to this lamp.

The air-feed is from the lower portion of the bonnet downward in the annular space between the glasses and through the bottom horizontal gauze to the flame. This arrangement increases the lighting efficiency by preheating the inlet-air.

The weight of the double-glass lamp shown in the illustrations is approximately 4 pounds 2 ounces uncharged, and 5 pounds 4 ounces when charged for a 10-hour shift. The weight of earlier acetylene safety-lamps was approximately: Wolf lamp, 4 pounds 10 ounces uncharged; Tombelaine lamp, 4 pounds ½ ounce uncharged; with a burning time of about 10 and 8 hours respectively. The weight of the Chance lamp when charged is less than either of the older types would be when charged to burn 10 hours.

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* The writer has already shown (see *Trans. Inst. M.E.*, 1916-1917, vol. liii., page 234) that this is a purely theoretical and not a sound practical objection, but in everyday life it is not so much facts which require to be made convincing as prejudices that have to be overcome.

The Chance lamp requires a charge of from 7½ to 8 ounces of carbide for 10 to 10½ hours' burning time. After about 4 hours' working, it is desirable that the water-vessel should be refilled, through the spring plunger filling-hole. Actually, the water-vessel contains enough water to run a full shift, but during the later hours the gas-pressure drops if more water is not added.

The lamp is of the lead-rivet locking type, with slip-ring. The one lock completely secures both the whole of the generator parts and the internal fittings of the lamp itself.

A minor advantage of the acetylene-lamp is that it can be stored ready charged, precisely the same as an oil or benzene-lamp, and will be immediately ready for use when required.

The points in favour of the Chance acetylene safety-lamp appear to be as follows:—(1) Increased illumination; (2) availability as a gas-detector; (3) facility afforded for roof inspection; (4) reduced risk of extinction; (5) increased safety; (6) absence of perishable joints; (7) portability and absence of deterioration during storage.

It is for the members to point out its disadvantages, in order that remedies may be found and the problem of effective mine-lighting carried another step nearer the goal.

Mr. G. L. KERR (Glasgow): Has this lamp been tested at the Government station at Eskmeals, and have any records been obtained as to its efficiency for gas-testing?

Mr. WILLIAM MAURICE (Sheffield): The lamp has not yet been submitted for test.

The PRESIDENT (Mr. G. Blake Walker): Has it been tested in the United States?

Mr. MAURICE: No. The inventor, Mr. T. M. Chance, became immersed in war activities before he had an opportunity of making the necessary arrangements. Formal approval of a lamp by the United States Mines Department is not, I understand, a necessary preliminary to its use underground.

Mr. W. C. MOUNTAIN (Newcastle-upon-Tyne): How does the cost work out, including depreciation, ordinary wear and tear, and keeping the lamp in proper working order, and what is the weight of the Chance lamp as compared with that of an electric lamp?

Mr. H. Eustace Mitton (Codnor): I must compliment Mr. Maurice on having produced a lamp which gives an exceedingly good light, but I confess that I am disappointed to hear that it has not been tested in the mine. The question of lighting mines is an important one. I attended a deputation only within the last fortnight, and was told most emphatically by the leaders of certain sections of the men that after the war the electric lamp would have to be installed in the mines, and that no oil-lamp would be permissible except for testing for gas. I have under my charge mines lit by candles, by oil-fed safety-lamps, and by electric lamps; but if I could with perfect confidence put in a lamp of such illuminating power as the one before us, of a reasonable weight, and procurable at a reasonable cost, suitable for gas-testing and adapted to all the other conditions of a mine, then I think there would be no reason to fear the workmen insisting on the use of electric lamps. There are many advantages and disadvantages in connexion with electric lamps. I have learnt during the past few years many lessons in respect to their use, and if at some future time it were thought that it would be interesting for me to give the benefit of my experiences with them, I should be very glad to do so. I think we ought to do all we possibly can either to improve our present oil-lamps or to introduce some other illuminating power that will give a light equal to, or better than, that of an electric lamp. Can Mr. Maurice state why the Government have refused to test the Chance lamp?

Prof. L. T. O'Shea (Sheffield): Mr. Maurice speaks of the valve serving "to shut off gas or to lower the flame for methane-testing." To what extent can he reduce the luminosity of the acetylene-flame so as to make a methane-cap visible? Is that possible with an acetylene-lamp?

Mr. W. D. Lloyd (Altofts): There is one point which, if Mr. Maurice has overcome it, will go a long way to make it possible for an acetylene-lamp to be used in fiery mines, that is—can he keep the lamp from going out? If the light is lost—and in some acetylene-lamps it is easy to lose—a volume of inflammable gas accumulates inside the lamp and if the lamp is then reignited, there will be an internal explosion.

Mr. R. W. Dron (Glasgow): Will the lamp give sufficient warning in the presence of danger from firedamp or blackdamp?

Mr. **GEORGE SPENCER** (West Hallam): How long would it take to charge and clean an acetylene-lamp as compared with an ordinary lamp?

Mr. **W. D. LLOYD**: Is it not a fact that you can get an acetylene-lamp that will burn in an atmosphere containing only 14 or even 12 per cent. of oxygen? From that point of view the lamp would be a source of danger: a man might get into an atmosphere which would not support life, and the lamp would still go on burning.

Mr. **H. KIRK** (Sheffield): If Mr. Maurice can do anything to bring this lamp into use in the mines, he will, by making the work more attractive and by removing one of the grievances under which the miners profess to labour, have done good work. In the absence of a Government test, could not the Institution through its Council use its influence to get the lamp tested, and so help its introduction into the mines?

Mr. **MAURICE**, in replying to the discussion, said: With reference to the question of testing, the lamp will be submitted in due course. It is, however, known fairly accurately what an acetylene safety-lamp will do under test conditions, and there is no reason to suppose that the Chance lamp will prove any less satisfactory than others; on the contrary, more is expected of it. The explosive range of mine gas in mixture with air lies—speaking from memory—between 5·5 and 13·5 per cent., and that of benzene and air between 2·5 and 5·5 per cent. The explosive range of acetylene-air mixtures is much wider. The lowest point lies at 3 per cent. and the highest at 75 per cent. The most dangerous mixture is, I think, about 40 per cent.

The explosion of any such proportion as this will undoubtedly pass the flame through two gauzes, and if there is methane in the mine air an explosion is fairly certain. The problem to be solved is to so design a lamp as to make the production of a 40-per-cent. mixture—or any acetylene-air mixture of explosive proportions—absolutely impossible. Comparatively feeble acetylene-air mixtures near the lower limit of explosibility do not produce explosions which will pass through the gauze, even in the presence of small percentages of methane. The enormous advantage to be derived from materially increased intensity of light ought to induce the Mines Research Department to take up the problem, and perhaps redetermine the ranges of explosibility and other desirable data.

With regard to cost of maintenance, there is very little data available at the moment, but the cost will probably be less than that of electric lamps. The fuel cost can be determined quite readily. The carbide consumption is approximately half a pound per shift, and the cost of carbide to-day is £40 per ton. This figure is abnormal, and probably the future cost will be nearer £30 per ton. The price will depend mainly on the cost of coal, carbide being made from coal and lime.

The flame in the Chance lamp can be turned down so as to become non-luminous, but a little skill is needed to prevent the low flame from going out. When burning normally, it is almost impossible to put it out, and if an extraordinary draught did extinguish it, it would be relit automatically.

I have taken up the lamp because I am convinced that it is possible to obtain a much better light from this source than from any other at present known. The electric lamp has had a very bad set-back owing to the war. In 1914 there were strong probabilities that a half-watt lamp suitable for mine lamps would be available. Such a lamp would either give twice the burning hours with one charge, or it would give double the light for the same time. Other developments were also then pending which would have placed the electric lamp in a much better position than it can fairly be said to occupy at present. It is, therefore, not yet time to say that the electric lamp has been tested and found wanting. On the other hand, there is no possibility of getting 8 to 10 candle-power out of any electric lamp, whereas that is well within the range of an acetylene-lamp. As to why the Mines Department declined to test acetylene-lamps, I should explain that no formal request has ever been made. I suggested, some years ago, my intention to submit a lamp for test, and the answer I received was that it would not be accepted. I think the explanation is that it is considered impossible to design an acetylene-lamp that will not continue to generate gas when the light goes out, and that the gas so liberated will form an explosive mixture in the mine. There is no doubt that an acetylene-lamp will pass the present statutory tests. The point is (assuming for the moment that an unlit lamp cannot be prevented from generating gas): will the gas set free be a source of danger? My view is that a whole pit full of lamps, liberating their entire output of acetylene, would not in any ordinary ventilating current produce an explosive mixture. There may, however, be some risk in headings and similar places. I think another objection was that the earlier types were fitted with internal re-lighters, and these were certainly undesirable in acetylene safety-lamps. The automatic principle developed in the new lamp does not, so far as I can see, carry with it any kind of risk. The flame can, with a little practice, be lowered quite easily for methane tests. (Mr. Maurice then gave a demonstration by reducing the light in the acetylene-lamp to an extremely fine point—sufficiently small to enable gas-testing to be carried out.) It is unfortunately impossible to demonstrate

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Mr. Spencer has asked what time is taken for charging and cleaning. In a suitably-organized lamp-room the labour would be about the same as for oil-lamps. The only point remaining unanswered, I think, is with regard to the suggestion that the Institution should interest itself in getting the lamp tested. I think, however, it would first be better to submit the lamp in the usual way. I appreciate the proposal, especially as there is no commercial interest involved—at any rate, for some time to come. My object in introducing the lamp is solely to open up discussion on the technical aspects of lighting mines by acetylene-lamps and to maintain interest in the whole problem of underground lighting until it has been completely revolutionized. I think there ought to be no rest until the working-places of mines are as well-illuminated as any modern workshop.

Mr. GEORGE SPENCER: It occurs to me that carbide is a product of which we have the raw material in this country. I heard the other day that it is proposed to erect huge bye-product works—their magnitude may be measured by the fact that it is expected that the coal-consumption will be 10,000 tons per week—and carbide will be made on a great scale, so that it will probably become very cheap indeed.

DISCUSSION OF DR. CHARLES CHREE'S PAPER ON "TERRESTRIAL MAGNETISM IN RELATION TO MINE SURVEYING."†

Prof. L. H. COOKE (London) wrote: The Institution is to be congratulated on having secured a paper on the subject of terrestrial magnetism from Dr. Chree, a magnetician of the highest standing, who has specially applied his science to our needs, and afforded us an admirable introduction to its literature. Many misconceptions on this subject are current among us, and have even found their way into our text-books; thus, it is often stated that the needle points to the terrestrial magnetic poles; or, again, with greater appearance of precision of phrase, that the planes of magnetic meridians of different places intersect at the terrestrial magnetic poles; or, again, that the needle is subject here to violent disturbances which *frequently* amount to one or two degrees! Dr. Chree's paper will dispel many such foggy inaccuracies incidentally, but its chief service will be to shatter the blind unreasonable faith in the random misuse of the needle.

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* *Trans. Inst. M. E.*, 1916-1917, vol. liii., page 232.

† *Ibid.*, 1917-1918, vol. lv., page 223.

The main source of trouble is the reference of our surveys to a "mean magnetic meridian"; then follows the misconception that we can determine the "mean magnetic meridian" with a compass, a dial, or a compass-theodolite, despite the fact that the sighting plane (plane of collimation) of the instrument is never parallel with the zero-line of the needle-scale; that the geometric axis of the needle does not as a rule coincide with its magnetic axis; that the pivot is never exactly at the centre of the needle-ring; that the line joining the two points of the needle does not pass through the point of the pivot, etc. Naturally follows the crude notion that from a map of isogonals, or from a list giving the declinations at various places, or by application to a magnetic observatory, true or geographic north can be found by way of a knowledge of the mean magnetic declination. Dr. Chree specifically condemns two of these fallacious modes of proceeding, but the tale of errors will never be ended except by a more rational training and stricter testing of the mine-surveyor, a point made by Mr. W. H. Galletly.

Again and again, surveyors blame the instrument-makers because no two compasses will give exactly the same measure for the magnetic azimuth of the same draft. I have in my charge an instrument which has the trough-compass attached 5⅓ degrees in error, but I considered its enormity a rare piece of good fortune: for even the most negligent of students could see that the instrument was faulty and be induced to interest himself in the simple and ready means of neutralizing the error—namely, by the aid of a line of orientation. A few years ago Mr. E. W. Newton, the well-known instrument-maker, of Camborne, Cornwall, showed me his records of tests of groups of needles, each group having been cut from the same strip of steel. When placed one after another in turn on the same pivot in the same compass, the readings they gave differed commonly by a few minutes up to about ½ degree. The non-coincidence of the magnetic and geometric axes of the needle and the failure of the line joining the two points of the needle to cut the supporting point—one, or the other, or probably both together—were doubtless the causes—almost if not entirely irremediable. The orientation-line, rationally used, cuts out not only the constructional blunders like that of the 5⅓ degrees just mentioned, but also these irremediable errors, as well as that due to the eccentricity of the pivot; and largely reduces errors arising from the regular and irregular changes in the position of the magnetic meridian.

The use of maps showing "smoothed" isogonals is recommended in error by almost all the recent British text-books on mine-surveying, a fact which lends force to Dr. Chree's warning; his further hint that even the unsmoothed isogonals of Nos. 5 and 9 of the Rücker and Thorpe maps do not tell the whole truth, should help to keep surveyors from attempting to take a value for the magnetic declination from any such map, if the value is to be used in good work in mine-surveying. Here and there in some of the northern coalfields are volcanic necks piercing the Coal-Measures; such bodies of more or less basic rock may cause local disturbance which will generally escape representation on small maps. Dumbarton Rock is such a neck (not in the Coal-Measures) where a century ago a compass set up at various points on a straight line running nearly tangent to the neck showed very discrepant measures of the azimuth of the line. The late Mr. J. Henderson* and Mr. W. Thomas† have both called attention to great deflections of the needle they have encountered in their surveys of Cornish mines; and an acquaintance, when surveying a certain colliery, finds the magnetic meridian fairly abruptly departs from its usual position when passing from one part of the colliery to another part. Possibly in such cases of areal disturbance, the surveyor should make use of several lines of known orientation, as, for example, the lines of a triangulation system. Fortunately such local disturbances seem to be relatively rare in our collieries, but it would be of interest and value to learn whether the local disturbing agencies affect the temporary change (diurnal variation and irregular disturbance). In other words, can the Kew data be usefully applied in such cases?

Mr. G. W. Walker states that the effects of the rock, the presence of iron railways or electric currents in the mine, and secular and daily variation of the normal magnetic forces make the use of surface values even near the mine quite inadmissible underground. This might be discouraging if magnetic orientation were a thing born only yesterday; but it has had a scientific basis for three-quarters of a century in Germany, and the scores of successes attained are ugly facts for Mr. Walker's views.

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* *Trans. Inst. M. E.*, 1894-1895, vol. viii., page 273.

† *Ibid.*, vol. ix., page 423.

One striking example is worth quoting: mine-surveyor Schmiedicke* made an underground traverse between two plumb-wires suspended in shafts 550 metres (600 yards) apart, conditions which afford a trustworthy means of finding the azimuths of the drafts. Two drafts were afterwards oriented magnetically, with results as follows:—

Draft.		Azimuth from traverses.	Azimuth by way of magnet.	Difference, in seconds.
1 to 2	..	155° 31′ 08″	155° 30′ 42″	26
43 to 44	..	359° 15′ 32″	359° 15′ 37″	5

We cannot hope to approach such accuracy unless we adopt instruments with filar suspension of the needle. Apart from the body of evidence obtained in mine-surveying practice, the practical concordance of the regular and irregular variations of the declination at the surface and underground has been established by the synchronous tests organized by Bergrat E. Borchers in an observatory at the surface and in another 545 metres (596 yards) underground in the Eleonore Mine, Clausthal, at intervals during the years 1843 to 1846. This was the first time that comparative observations had been made at so great a depth, and for their trustworthiness speaks the reputation of Borchers, a magnetician, an inventor and improver of mine-surveying instruments, appliances, and methods, and a scientific mine-surveyor whose wonderful results in practice were the admiration of his age.† Earlier observations in the Freiberg mines, and later ones by Obermarkscheider Schmid and the magnetician Liznar for a depth of 1,000 metres (1,094 yards) in the deep Adalbert shaft at Przibram confirm Borcher's observations, and tend to show that Clausthal is not an exceptional case. So far the observations were at most made no more frequently than every 5 or 15 minutes, but in 1906 self-registering observatories were installed at the surface and 813 metres (889 yards) below, in the Monopol Colliery, Westphalia, and the tests were conducted by mine-surveyor Stiepel, who had been specially trained at Potsdam. No noticeable difference showed itself in the curves of the two stations on quiet days, or on days of irregular but slow disturbance, and no noteworthy discordance in the quicker swings.† In 1903 L. A. Bauer investigated the possibility of operating self-registering instruments in the Lake Superior copper-mines and found the conditions exceptionally good, in the absence of electric installations, at a depth of nearly a mile below the surface; but delay in the delivery and the defective character of the German instruments prevented the carrying-out of the work. Owing to electric installations, the conditions are no longer favourable. Mr. T. Russell § of the Great Lakes Survey reported that in the Tamarack, 4,760 feet below ground, the diurnal range of the declination and the times of elongations were about the same as those observed at the surface, while the dip was 27 minutes less.

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* *Mitteilungen aus dem Markscheidewesen*, 1901, page 14.

† E. Hoppe, *erg- u. Hüttenmännische Ztg.*, 1884, page 427.

‡ Ad. Schmidt, *Meteorologische Zeitschrift*, 1907, vol. xxiv., page 131.

§ *Mining and Scientific Press*, 1906, page 160.

From the body of evidence it would seem that we may arrive at the important practical conclusion that the underground magnetic declination and its regular and irregular variations are much the same as at the surface if there is no great mineral or artificial disturbance; and the absence of mineral disturbance is fairly general in our coalfields.

But magnetic research is much wanted in disturbed areas whether shown in, or omitted from, the Rücker and Thorpe maps. Mr. V. Watteyne* has called attention to the distortion of the plans of some Belgian collieries owing to the non-verticality or twisting of the magnetic surfaces of force; and Prof. Haussmann and his students in the Diepenlinchen zinc-mine have shown that it is probable that the run of the magnetic lines of force at grass differs from their underground course.

But these irregularities seem to be rare exceptions, as rare as those for difference of elevation at the surface. One would like to know what correction Mr. Walker applies for difference of elevation in his surface-surveys. Doubtless with every change in elevation or profundity there is some change in declination; but, according to the available evidence, the amount must be very minute whether man observes on the mountain-tops or in the mine-bottoms. Commonly in surveying in a district free from local disturbance one can rely on the same value of the declination holding good for a mile at the surface; and on *a-priori* grounds one may believe that the change will be generally much less for a mile of depth than for a mile horizontally.

While the British Empire has allowed Germany a three-quarters-of-a-century start in magnetic orientation, her Roberts-shaft-plumbing-system stands well ahead of all other methods in the world for orienting an underground survey from a single, deep, vertical shaft independently of the needle. The optical methods appear to break down in depth, owing to difficulties of visibility, and perhaps also of air-refraction and -reflection, which will give food for consideration of the Ordnance Survey when they are easily transferring the geographic meridian to the bottom of deep shafts. The optical-plumbing method of the geodesian Nagel is no longer applied even in the county of its origin or in Austria, and its description has been deleted from the latest text-books. The method with the miner's transit-instrument which he has modified from the astronomical instrument (not the transit-theodolite or the misnamed American "transit") has a far surer scientific foundation and better chances of success. While this purely British method overtops all its optical rivals, and with the improvements introduced by Prof. E. Liveing and Prof. G. R. Thompson permits of reducing the mischances of vibration, refraction, etc., by repetition and averaging, it halts at a moderate depth, owing to limitation of visibility, and awaits further aid.

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* *Trans. Inst. M. E.*, 1902-1903, vol. xxiv., page 496.

More than one contributor to the discussion has questioned the applicability of the Kew data to the whole of our coalfields, and Dr. Chree himself states that science is so little advanced that he is not in a position to say what is the desirable number of observatories in this country. As the publication of the Kew data arose out of the writer's proposal to procure a self-registering declinometer for the Royal School of Mines and to extend the benefits of its records to the country, it is perhaps desirable to state the grounds on which that proposal was made. Apart from its educational uses for staff and students, it was hoped to stir up a greater number of surveyors in this country to take an interest in diurnal variation and irregular disturbance as a probable source of the occasional waste of their efforts or the occasional poor quality of their results. While one recording instrument was looked upon as a good and useful *beginning* only, it should be recollected that Rücker and Thorpe in their magnetic survey reduced to the epoch January 1st, 1886, used a correction which was the algebraic sum of the diurnal variation at the local time and of the disturbance registered at Kew at the Greenwich mean time at which the observations were taken (Bakerian Lecture, 1890, page 65). They applied the Kew data over the whole of the British Isles, a much greater area than that of the coalfields, and, as a test of the validity of their procedure, they picked out stations in Ireland and Scotland, where two or more observations were made at times when the diurnal variations differed by more than 4′. Taking the extreme western and northern stations, for Westport they found the values 23° 5·5′, 23° 4·2′, 23° 5·4′; for Portree, 22° 21·6′, 22° 22·7′; and for Stornoway 23° 50·7′, 23° 48·4′, 23° 50·7′. The results for the coalfields, which are all nearer Kew and in perhaps less-disturbed localities, should be no worse, and may be better.

The late Prof. Brathuhn arranged a number of orientations at mines in the Harz in the neighbourhood of the Clausthal Observatory; in the Mansfeld copper district; near Barsinghausen, etc. The results were corrected in duplicate for diurnal variation and disturbance from the data provided both by the Clausthal Observatory at distances of from 7 to 62 miles, and by the Wilhelmshaven Observatory at the much greater distances of from 94 to 204 miles. The greatest difference of any pair of results reached only 47 seconds of arc, and the average difference of twenty-six results 18 seconds. Brathuhn thought in 1888 that he was entitled to draw the conclusion that a good central observatory in Clausthal would satisfy the requirements of mining and mine-surveying of the whole of Prussia. However, the lapse of time and further experience made him less confident, and in 1892 he wrote that if important orientations were in hand, the time from 10 a.m. to 2 p.m. should be avoided, because the change in the position of the needle, owing to the diurnal variation, was at a maximum in these hours, and places east and west might suffer from the difference of local time and consequent non-concurrence of the diurnal variation. In the later editions of his *Lehrbuch der Markscheidekunst* (*e.g.*, fourth edition, 1908, page 364) he extends his ban over the time from 6 a.m. to 3 p.m., unless the declinometer is in the immediate neighbourhood; he would have distant curves used only for evening and night-work, and then only if there were no disturbance.

Brathuhn probably had in mind the attainment of such fleckless results as those of Schmiedicke. As Dr. Chree's invaluable tables show the relative infrequency of disturbances in the morning hours, and as Rücker and Thorpe's corrections were fairly successful, it is possible that the Kew data may suffice—between 2 a.m. and noon—for most of our mineral fields. However, in the night-hours electric trams stop running and much other electric work ceases.

As irregular disturbances occur on the majority of days, and as the method of smoothing the curves tends to conceal the smaller vagaries of the magnet, a very great increase in the accuracy of the corrections for the fluctuations of the magnet would be secured if the Kew authorities would issue the actual declination curves smoothed only as regards artificial electric disturbance.

As the irregular disturbances and the ordinary diurnal changes in the northern and Scottish coalfields are slightly larger than those of the south, a further increase in the accuracy of the corrections would result if the declination curves of Eskdalemuir could also be published.

Proportional interpolation for places situated in the Midlands, etc., with perhaps, a slight further correction of the ordinary diurnal change for the difference of time or longitude, would probably give all the accuracy desirable for most of the important work of the surveyor. A better way of interpolating may be possible later.

His most difficult tasks, however, would demand the use of two instruments, especially, perhaps, in disturbed areas.

In any case, the use of a surface line of known orientation is desirable for comparison; and if surveyors would use the better-class old methods of orientation, compare their results with those corrected by the light of the Kew data, and publish their results, some guidance would be obtained for the future as to where scientific research could be best applied. The actual curves of Kew and Eskdalemuir would enable the surveyor to take out corrections to his magnetic azimuths for any 5 minutes of the day, and would reduce the uncertainty in the magnetic angles nearer the very desirable figure of 1 minute of arc. At the present time, perhaps, we can hardly expect such an expense to be incurred; but after the war, on the resumption of more normal conditions, the suggested improvement would doubtless receive the consideration of the Meteorological Office. Meanwhile, in addition to the two-hourly averages, or in place of them, the values of the Kew and Eskdalemuir declinations for points of time (not averages for 2-hour or other lengthy spells), should be published. I would suggest that the values for 7, 7-30, 8, 8-30, 9, 9-30, 10, 10-30, and 11 a.m. (G.M.T.) should be given. However, I have known many diallers to find it convenient to survey in the afternoon and evening and night, and although their hours are more liable to disturbance than those of the morning, it might be well to issue observatory values for such times, but at less frequent intervals. Moreover the possible freedom of the night-hours from troubles due to electric power is to be taken into consideration.

Dr. CHARLES CHREE (London), in reply, wrote: I have already received from Mr. George Spencer and others the suggestion that observations at one or more exact hours of the day might be a useful addition to the Kew declination data now being published. It is obvious that higher accuracy would be obtainable from such data if the observer took only a single reading at the exact hour. It is otherwise, however, if he took a series of readings at intervals throughout two hours. The Meteorological Office naturally wish to publish data in the form most useful to engineers, whatever that may be. I would be glad to have opinions on the subject. If results are desired for a definite hour, artificial disturbances—which after all are not large at Kew in the case of declination—can be fairly well eliminated by taking the mean ordinate for 5 or 10 minutes, centering at the hour. The difficulty at the moment as regards Eskdalemuir is that the magnetographs in regular use there do not directly record declination, but north and west components of force. The declination magnetograph which was once at Falmouth has, however, recently been moved to Eskdalemuir, and it is hoped to bring it into regular operation there.

There are really two distinct problems involved in the question of the identity of declination changes at the surface and in deep mines. If all declination changes were due entirely to overhead electric currents at heights of 50 miles or more, or if, while earth-currents contributed, only a very small fraction of these currents passed within a mile of the surface, then the changes of magnetic force at the surface and in ordinary mines should be practically the same. On magnetically quiet days the changes of magnetic force at the surface and at considerable depths do appear, as Mr. Cooke has pointed out, to be at least closely alike; but on days of large or considerable disturbance there seems to be a lack of information on this point. The second problem is: what would happen in the case of considerable local disturbance—for example, from basaltic rock? To take a simple illustration: suppose two magnets suspended in two different magnetic fields, the horizontal force having the same direction in the two fields, but different intensities, which stand to one another in the ratio of 6 to 5. If equal magnetic forces act on these two magnets in the direction perpendicular to their undisturbed positions, which would be parallel, then if the magnet in the stronger field were deflected through 5′, that in the weaker field would be deflected through 6′. In the case of ordinary local disturbance, the direction of the magnetic field, the local magnetic meridian, is affected as well as the controlling force. Thus the problem is more complicated. I hope it will be possible to make a careful study of declination changes at Kew and Eskdalemuir, with a view to the best possible utilization of the data for engineering purposes; but that means a great deal of research, and under existing conditions it is difficult to give the necessary time and thought.

DISCUSSION OF DR. J. S. HALDANE'S PAPER ON "THE EFFECTS OF DUST-INHALATION."*

MR. E. H. CLIFFORD (Johannesburg) wrote: The evil of miners' phthisis has attained such proportions, and has been attended with such tragic results on the Witwatersrand that Dr. Haldane's paper is most welcome, because there has always been an impression in my mind, and possibly also in that of other engineers responsible for the practical work of suppressing dust, that the physiological side of the problem is one about which there remains a considerable degree of uncertainty.

Very large sums of money have been spent and infinite trouble has been taken on the Witwatersrand in preventing the inhalation of dust. An elaborate organization is constantly at work dealing with this matter with a view to find out where the dust originates, to prevent its production, to lay the dust that is unavoidably made, and, if neither of these things can be done, to prevent men from breathing the dust-laden air. In addition to the humanitarian aspect of the problem, which is of sufficient importance in itself, the cost of these measures amounts to a huge figure, and it will be readily appreciated that we are particularly anxious that the physiological data on which all this work is based shall be indisputable.

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., page 264.

The results of many thousands of determinations of dust in the mines of the Witwatersrand indicate that the amount breathed by the average man cannot be a tenth of what it was formerly. This is the result of the drastic measures above referred to, and has been followed by a marked diminution in the incidence of miners' phthisis—a diminution which still continues, although latterly the rate of improvement is very much less than it was some three or four years ago.

I am not competent to discuss questions of physiology, but would like to suggest to Dr. Haldane that the physical state of the dust-particles, such as the size, external form, crystallographic state, etc., may also have some bearing on the incidence of the disease. I am rather confirmed in this view because of an observation made by Dr. Haldane, in which he compares the noxious Mysore dust with the extremely dangerous dust of the Witwatersrand. As a matter of fact, although the Witwatersrand quartzites are composed of roughly 85 per cent. of free silica, 7 per cent. of alumina, and the balance mostly pyrites and sericite, the dust is of a very different composition, namely, 70 per cent. of silica and 22 per cent. of alumina. Further, there is also present in the mine atmosphere a considerable quantity—about 15 per cent.—of carbonaceous matter, so that the amount of free silica in the total dust is not very much more than that which is present in Mysore dust. Moreover, dust collected in the streets of Johannesburg, which is not known to cause phthisis, is similar in composition to mine dust, and is often present in enormous quantities, but the particles are generally rounded.

There is presumptive evidence to the effect that dust is not dangerous unless it is fine, that is, from about 5 microns in diameter downwards, but there is not much certainty about either the upper or the lower limit. Various examinations have been made of dust *in situ* in lungs and analyses of lung tissues. The results do not agree particularly well. According to some authorities, the diameter of the dust ranges from 2 to 3 microns; according to others, nearly all the dust is smaller than 1 micron. As to the amount of dust smaller than ¼ micron in diameter—that is, below the limit of visibility—nothing is known. It would clearly be wrong to assume that such very fine dust does not exist; in fact, it may be that it forms a considerable proportion of the total weight, and probably the greater part of the total number. It is important, from a practical point of view, to settle this question, because we can then determine which is the more correct way of expressing the state of the mine air, whether by stating the number of particles per unit volume, or the weight per unit volume. A count of the number of particles is always wrong, partly for the above-mentioned reason, and partly on account of serious practical difficulties. On the other hand, a gravimetric measurement may be entirely nullified by the unsuspected presence of a few large particles. In the present state of our knowledge, therefore, the only safe course is to take observations by both methods concurrently.

Reverting to Dr. Haldane's hypothesis as to the effect of "neutralizing dust," it would be interesting to know whether he considers it necessary that the neutralizing dust should be inhaled simultaneously with noxious dust, or whether this is unessential. In our mines the air is saturated with moisture and every rock surface is kept wet, conditions which would render it impracticable to maintain a supply of dust in the mine air. It would be much simpler and easier of control if the administration of dust to the men could be made by some simple dusting contrivance after they come up from the mine. A further question that arises is whether the neutralizing dust will have a curative effect, or whether it is only likely to be preventive.

It is greatly to be hoped that immediate steps will be taken in this country by properly-qualified people to carry out further experiments on the lines suggested in Dr. Haldane's most valuable paper.

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RECENT DEVELOPMENTS IN THE COALFIELDS SOUTH OF SYDNEY.

DR. J. R. M. ROBERTSON.

Introduction.—In a paper on "The Coalfields South of Sydney, New South Wales,"* published in 1892, reference was made by the writer to the presence of basaltic dykes and intrusive sheets in the coal-seams, and to the presence of irregular occurrences known as "rolls" on the floor of the upper coal-seam in certain areas. At that time comparatively little was known of the physiography of the coalfield. Although during the intervening years its limits have not been extended, the then existing collieries have increased their outputs, owing to the demand for steam-coal, and new collieries have developed areas that had been abandoned or were unworked at the date of the last communication. These developments have added to the general knowledge on the subject, owing to the extensions of underground workings, and the boreholes and shafts that have been sunk, and have cleared up some matters that were then in doubt. It is proposed in this communication to confine attention to the information obtained by these subsequent developments.

Basaltic Dykes and Intrusions.—No very direct evidences of these are generally seen on the surface apart from the character of the soil or the luxuriance of the vegetation that results from their decomposition. Sheets, dykes, or masses of basalt occur at points on the high plateau that extends westwards from the crest of the coastal range, on some of the headlands and islands, and on the level land extending from the foothills to the coast that has been fertilized by their decay. The majority of these have issued from fissures, or from the line of pre-existing faults, and may be seen in some of the railway-cuttings or in recently-opened quarries. When they come into contact with bituminous or Carboniferous stratifications, as a rule they lose their natural appearance, and become changed (even at considerable depths) to a whitish or greyish-green colour that in the presence of moisture and air rapidly becomes a soft, unctuous, and putty-like substance.

There is evidence in the Illawarra Coalfield of two eras of volcanic forces: one series of strong hard dykes intersects the strata in an east-and-west or west-south-westerly direction;

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* *Trans. Inst. M. E.*, 1892-1893, vol. iv., page 83.

another, and the more numerous, intersects these and the measures in a north-north-westerly direction. The latter are more liable, in the writer's opinion, to be deflected from straight lines. When met with in the colliery workings, both of these are white or grey in colour. The former may singe or burn the coal-seam for a few feet on either side, while the latter often unfortunately spread out over large irregular areas, following roughly the bedding of the coal-seams, which may be obliterated or partly consumed. Owing to the great strength and the unyielding nature of the thick embedded sandstones that overly the upper or separate some of the other coal-seams of the series, molten matter issuing from the natural cracks or cleavage-planes under pressure has been forced to flow on the top or at the bottom or along the bedding-plane of the coal-seams until a crevice or weak portion of the roof provided an exit upwards.

The extent to which these intrusive sheets or masses have destroyed or affected the coal-seams will be hereafter referred to. Figs. 3 to 8 (Plate IV.) illustrate the nature of these troublesome occurrences. An ordinary clean well-defined dyke is easily dealt with, but to attack a cindered coal-area more or less obliterated or clinkered by these floating masses of basalt is a very serious and uncertain proposition.

It is now known that some of these basaltic intrusions have issued or have exuded from the more or less fractured lines of faults, or from crevices of the sandstone rocks, or from the edges of "rolls." Sometimes isolated areas of coal-seam are found badly cindered or burnt where no basalt is visible. The coal in this case has evidently been burnt by the transmission of intensely-heated gases from below. In other cases a layer of white dolerite on the roof of a coal-seam may render it unmarketable until the layer disappears (Fig. 5, Plate IV.). In one of these sections a mass of basalt has occupied and completely obliterated the lower half of the seam, whilst the upper portion has been protected by a thin layer of fine clay. So very uncertain are the incidence, influence, and distribution of these intrusive and destructive basalts that, while the coal-seam may be cindered in one heading of a pair, it may be quite unaffected in the other. With these preliminary and discursive remarks the writer will now give the outline of some extensive prospecting operations that were undertaken with a view of ascertaining the extent or width of a long line of cindered coal that during a period of 20 years had gradually cut off the western workings of Woonona and Bulli Collieries for a distance of about 2 miles (Figs. 1 and 2, Plate IV.).

The irregular eastern fringe of this disturbed area very closely follows the line of the cliffs of the coastal range that at this point rise to a height of about 1,200 feet above sea-level. Beyond and to the west of this area the respective companies held large areas of coal-bearing land on the plateau that extends many miles in that direction. The outcrop of Bulli Colliery extends along the talus of the coastal range about 480 feet above sea-level, and is continuous with the outcrops north and south. The general dip of the coal-beds throughout Illawarra is slightly to the north of west. A few chains to the north, and running parallel to the Bulli main tunnel, is a 90-foot downthrow fault to the north. One and a half miles or so to the south, the coal-workings of Woonona Colliery had in the early days impinged on and to the west were stopped by cindered coal. Further to the south, South Bulli Colliery had also in the early days been abandoned on a network of basalt dykes and patches of cindered coal. Midway up, the South Bulli incline is crossed by a strong and thick basalt dyke, bearing north-north-west, and intersects the mountain range, its course being marked by rich vegetation and a marked depression. This dyke separated the workings of South Bulli from those of Woonona.

About 30 years ago South Bulli Colliery was recommenced, and the headings driven a short distance west passed through the area of disturbed coal. The workings of this colliery are entirely on the western side of the large dyke and the long line of cindered coal which the workings from Woonona and Bulli have proved. The writer in his previous paper stated that apparently this main dyke was the cause of the cindered coal in these collieries. The extension of the South Bulli workings to the north gradually delineated the western contour of cinder, while those of Bellambi, which likewise had recommenced, proved an irregular fringe with deep bays of coal. It was then seen that the workings of these two collieries had at one point approached each other where the coal was less cindered. As these collieries were owned by the same company, a mine was driven across the main dyke and disturbed ground that separated them, and by thus connecting two opposing inlets or bays of coal, enabled Woonona to assist in ventilating Bellambi workings and augmenting its output from the western side of the dyke and cinder coal.

Returning to Bulli, from the northern 90-foot downthrow, at a point 70 chains in-bye from the adit, it was found that a mass of hard basalt had issued and spread in the coal-seam. The main tunnel passed through this, and proved that the fault had swerved 30 degrees to the north. Twenty chains further the tunnel encountered another and larger mass of basalt that had also emerged from the line of this fault. This basalt extended across the workings and joined or disappeared in the cinder-coal to the west. Prior to this work the company had begun to drive a new pair of tunnels half a mile to the north of the 90-foot fault. After exploring in every direction, and finding nothing but coal cindered by layers of intrusive dolerite, the tunnels were abandoned. A series of bores along the northern outcrop proved nothing but cindered coal and basalt in the position of the seam. It was evident that the intrusive basalt that caused so much destruction in this section had issued from the 90-foot fault.

While the general dip of Illawarra coal-seams is to the west or north-west, Bulli main tunnel rose in that direction 1 in 24. Evidently this condition has been caused by the uplifting of the strata by stupendous volcanic forces to the north and west in front of the tunnel. The 90-foot fault has since been traced to its junction with the basaltic disturbance to the north and west, which are freely connected by dykes (Fig. 2, Plate IV.).

In the south tunnels of Bulli, where many years ago the first indications of cindered coal were observed, a thin white thread was first seen in the centre of the upper coal-seam. This thread slowly increased in thickness, gradually affecting the coal. After driving 130 yards (Figs. 3 and 4, Plate IV.), this dolerite intrusion was found to have increased to 3 feet in thickness, destroying the seam both above and below it. Believing that the lower or 4-foot seam (21 feet below) might not be affected, a shaft was sunk, and as the coal was unaffected the exploring drift was continued in the lower seam, going due west. After driving west 100 yards, two basalt dykes were crossed, when the coal-seam became cindered first on the floor and then on the roof. The seam soon became unrecognizable, and when 250 yards had been driven the main dyke (105 feet thick) was passed through. Beyond it the coal-seam became reticulated with strings of basalt; several dykes were cut, but as the coal-seam became obliterated and the prospect hopeless, further exploration was suspended. Two bores were then put down well ahead, and cindered coal and basalt proved. The gradient of this southern drive was 1 in 35 to the west.

The question of finally abandoning the colliery was seriously discussed. Nearly the whole of the long line of workings was cut off by an irregular line of cindered coal and disturbed country of unknown width, and very large sums of money had been spent without result; but in front, and possibly beyond this disturbed zone, the company held several thousands of acres of land. After giving the case most careful consideration, the writer pointed out to the owners that without doubt the disturbed country must prove but a belt, the western limits of which (though 1½ miles or more distant) was being defined by South Bulli working. Although no one could estimate its extent, the writer considered that ½ to ¾ mile of drives would in all likelihood prove good coal, and that so far as he could judge the southern drive previously described had nearly proved its width at that point. After considerable hesitation, the owners resolved to at least drive a pair of exploring headings for 880 yards.

A plan and sections of these drives are shown in Figs. 2 and 9 (Plates IV. and V.), an examination of which will obviate a lengthy description. From the commencement the coal-seam began to dip irregularly from 1 in 10 to 1 in 14 to the west. From the beginning the baneful effect of the injected basalt became more and more pronounced every yard the drive advanced. On crossing a roll about 70 yards from the commencement, actual basalt appeared in the roof, the thickness of the seam decreased, and soon became a clinker. After crossing two small rolls, the basalt in the roof increased and a coarse brown scoriaceous stone occupied the floor. Between these was a thin layer of highly-transmuted coal. This tapered away to a few inches thick, but continued in the centre of the seam until an oblique dyke cut it off (*b*, Fig. 9, Plate V.). The coal-seam was now unrecognizable, and workmen were guided by a smooth bed on the floor and occasional ridges which were taken to be "rolls" (*a*, *b*, *d*, Fig. 9). Three large and very hard rolls, and then the main dyke, 100 feet in thickness, very hard and white, were crossed (*e*, Fig. 9). When clear of the main dyke, a sharp depression occurred between two narrow dykes (*f*) of very white dolerite; then basalt occupied the roof of the drive, and the cindered coal rang like metal.

A few ridges or corrugations on the floor alone created a belief that the drives were following the position of the former coal-seam. At the foot of a most disturbed downthrow of 15 feet (5, Fig. 1, Plate IV., and *g*, Fig. 9, Plate V.), a patch of unburnt coal was found, but this soon tapered to a narrow band of black substance, with basalt above and below, and very difficult to work. The drifts had now been driven for 50 chains, and showed no prospect of normal conditions. The proprietors abandoned this exploring work to the west, but were induced to put down three deep bores farther west on the plateau. One of these, half-a-mile in advance of the drifts, proved 8½ feet of good coal at a depth of 1,080 feet; another, about a mile north of this, went down on basalt; while a third, ¾ mile west of No. 2, proved 9 feet of coal unaffected by basalt. Thus encouraged, work at the drifts was recommenced. For 5½ chains the coal-seam was obliterated, then suddenly a patch of coal—cindered below and clinkered above—was followed for 2½ chains (*h*, Fig. 9, Plate V.), the roof and floor being basalt. On crossing a small "roll," all appearance of coal disappeared (*i*, Fig. 9). A thin band of cindered coal occupied the floor between the rolls, which were now numerous. Above this thin layer of cindered coal the seam was unrecognizable, the roof being basalt. Gradually, however, a streak of clear coal appeared under the cindered portion; this increased, a roll was crossed, and the basalt disappeared from the roof at 69 chains from the commencement. The drift was now in thick but very disturbed coal, containing patches of injected basalt, but in another 5 chains all of these disturbances disappeared; and when in 8½ feet of excellent coal, but 300 feet below the point of commencement, winning-out operations were begun. After regrading the drives, endless-rope haulage was installed, and the old colliery entered upon a new lease of life.

It is extremely probable that the width of this cindered coal area (75 chains) increases to the north. When, if it extends so far, it reaches the latitude of the more northerly collieries, its eastern fringe will in all probability be found so far from the outcrop that it is unlikely any attempt will be made at these collieries to prove its width.

Intrusive basalt affects the lower coal-seams, so far as is known, in a similar manner, but probably more so. At one colliery where the upper coal-seam was normal over a wide area, sinkings to the lower seams showed these to be intensely burnt and cindered. At another a still lower seam was found to be utterly destroyed for a distance of at least half a mile. In Mount Keira—one of the most southerly collieries—at one point a considerable area of the thick upper coal has been transformed into a mass of pentagonal columns. This, of course, has been caused by the transmission of heat from below. While no exact data exist, undoubtedly very large areas of the southern coal-seams have been destroyed by comparatively recent volcanic agencies in the manner described, and this must militate against future developments in the rough and difficult country behind the precipitous coastal cliffs.

All the southern collieries have experienced in one form or another the effects of basalt. In one case (apart from dykes) an acre or two of coal are rendered unmarketable by a layer of white dolerite on the roof. In another the bottom coal is in like manner affected by basalt on the floor. In one colliery a pear-shaped mass of coal 2½ acres in extent, contiguous to an overlap fault, has been cindered, yet no basalt has been discovered.

"*Horses*" *or* "*Rolls.*"—These strange and perplexing occurrences were referred to in the writer's former paper, and he confesses his inability to arrive at a satisfactory explanation of their genesis, but in the hope that some members may be able to throw some light on their origin he will again describe them in some detail.

Their occurrence is confined to the upper seam and the thick-coal collieries between Mount Kembla main adit and the Bulli Collieries, a distance of about 10 miles. To the south of Mount Kembla adit the upper coal thins off, and these rolls dwindle to a few inches in height, or become a mere ripple on the floor. To the north of this adit they increase in height. They seem to bear a relation to the height of the seam. These "rolls" are much longer than they are broad; no two have the same height or configuration, and they seldom rise to the roof of the seam. As a rule, more or less coal intervenes between their apex or hump and the roof, which in the case of high rolls is somewhat tender at that spot. They occur as a series of ridges or corrugations that have a north-westerly bearing (Fig. 14, Plate V.). Often they occur so close together that one "room" or "stall" can extract the whole of the coal between them, the roll itself being left as a pillar. In certain zones a greater width of coal separates them. Where possible, cut-throughs connecting the "bords" are driven where the ends of these are lowest. A plan of these rolls shows that they follow more or less curved lines. Fig. 14 (Plate V.) shows the exact occurrence of these rolls in a district of one of the Illawarra Collieries.

As a rule, they begin with a fine point of hard arenaceous black bind that rapidly rises as a rounded hump-back and gradually disappears as it began. Occasionally one of these has a bifurcated end. In section and in profile they vary greatly (Figs. 10 to 13, Plate V.). Occasionally shreds or arms of coal are embraced (Figs. 10 and 12) by projections of shale, and one rounded side of the roll is generally steeper than the other. Their occurrence much resembles the arrangement of sand-dunes on the sea-coast, but they differ in that the ends are more tapering.

Some have suggested an aërial origin, whilst others are convinced they have been formed by mud-laden currents. Neither of these theories appears to account for their occurrence or appearance. The intricate way that projections of coal are occasionally imbedded within them is difficult to understand. In disturbed situations basalt has issued from the edge of their "hump," so to speak. The roof above the highest point is generally tender.

To the north of the 90-foot downthrow in Bulli Colliery they entirely disappear from the seam; neither are they found at the Metropolitan Colliery (the nearest working colliery to Sydney), where the coal-seam averages 12 feet in thickness. In some of the older collieries to the south they occupy a very large proportion of the original coal-seam, and wherever found they sensibly increase the cost of production. In the situations where they occur they can scarcely be considered of contemporary age with the coal-seam in which they are found. They are not due to pressure, nor are they a crumpling of the floor.

Faults" and "Dykes."—On the small-scale map of the district (Fig. 1, Plate IV.) the approximate position and course of the principal faults and dykes are delineated, and on the margin the "throw" of the faults and the thickness of the "dykes" are given. North of the Metropolitan Colliery, or to the west of the present colliery workings, nothing is so far known regarding these occurrences. On the coast-line of Illawarra there are many localities that have been the scene of stupendous volcanic activities, where masses of igneous rocks of various varieties have been ejected or spread as sheets over Carboniferous rocks. At Kiama, Shellharbour, Port Kembla, Wollongong, and its neighbourhood, and Towragie, near Bellambi Point, masses and sheets of igneous rock have issued, from which as centres dykes radiate and intersect the coalfield covered by the adjacent mountain ranges, and often and in a capricious manner destroy large areas of the coal-seams.

Bores put down north of Coal Cliff and eastward of the Metropolitan Colliery have revealed extensive areas of concealed basalt, the extent and baleful influence of which one has at present no complete conception. Intersecting the high plateau and on the rocky margins of Sydney's magnificent harbour, numerous igneous dykes are seen. In the presence of bituminous strata these dolerites become transformed, and lose their original character and appearance. In this condition they readily weather and dissolve. To their decomposition and dissemination by rains the rich soils and the diversified and charming vegetation of Illawarra is due. The stately and graceful palms, the groves of tree-ferns, the unique fire and flame-trees, and the dense evergreen scrub are sure indicators of the presence of igneous rocks which may themselves be invisible. On the towering sea-cliffs that guard the vast Pacific deep narrow clefts or fissures between perpendicular sandstone rocks indicate the position of igneous dykes.

Sydney Harbour Colliery.—The writer referred in his previous paper to two bores about 2,800 feet deep that had been sunk on the shores of Sydney Harbour and had proved the upper coal-seam of the usual thickness, but which was destroyed by the presence of basalt. London investors subscribed a large capital to purchase the leases that had for many years been held, with the object of sinking the colliery. Prevented by the authorities from establishing their works on one of the most beautiful and conspicuous headlands in the harbour, the company purchased about 4 acres of freeholds and water-frontage in a densely-populated district of Balmain, and built an extensive retaining-wall. Sinking operations for coal then began.

The site is about 4 miles up the harbour, and west of the two bores referred to. No difficulty was experienced in sinking through the unbedded Hawkesbury sandstones and conglomerates, and only an insignificant quantity of water was tapped in No. 1 shaft. The small quantity of water gave considerable trouble by depositing a sediment which rapidly choked the pipes through which it was led. Its effect on steel or iron was alarming. The 9-inch flanges and clamps securing 80-pound steel rail guides were speedily attacked and entirely corroded in 3 years. This water (see Appendix) contained large quantities of ferrous chloride, and this in presence of air would be converted into ferric chloride, which at once attacks iron or steel.

When the first shaft was well under way, the second, 18 feet in diameter and 150 feet distant, was begun. At a depth of about 680 feet a strong feeder of water was unexpectedly tapped. This water also rapidly attacked iron and steel. Fifty-three feet of cast-iron tubbing was put in to dam back the feeder, but upwards of 300 gallons an hour still found its way into the shaft. On approaching the Coal-Measures, considerable blowers of gas were met with. The main shaft reached a depth of 2,886 feet, but the coal-seam was found to be thin and worthless. It was divided by a stone band 2 feet 3 inches thick. The upper division of the coal-seam was 2½ feet thick and the lower only 8 inches. The dividing band of stone was inclined to thicken to the west and to thin to the landward or eastern side of the long peninsula, on the eastern margin of which, for some obscure reason, the shafts had been sunk. The company, however, had no claim or right to work coal under the land; it had already been alienated to the surrounding owners. The colliery lease only embraced the coal under the waters of the harbour. The company had therefore to obtain a special Act of Parliament granting permission to drive a pair of headings under the properties to the east and to emerge under a bay of deep indentation of the harbour 1,200 yards distant from the shafts. When this was obtained, two headings were driven in the coal-seam. The dividing stone band gradually decreased in thickness, the two divisions of the seam coalesced, and at about 1,200 yards from the shaft a seam 4½ feet thick was reached. The temperature exceeded 100° Fahr., the air was dry, and much gas was given off. The work of driving was difficult, and the shale roof began to " weigh " on the timber. The coal-seam increased to 6 feet in one part, but decreased in thickness to the north and south. A section of the shafts and of this exploring drive are shown in Fig. 15 (Plate V.).

It was determined to work the seam by longwall, with roads 43 yards apart, the skips being conducted along the faces. For this purpose the headings were widened and increased in height for safety and for ventilating purposes, after which they gave no trouble. The roof consisted of grey arenaceous schist under very hard sandstone, and came down easily if brushed at once and kept well up to the coal-face, but if permitted to sag it proved difficult and expensive to deal with. The quality of the coal was good, and closely resembled in appearance and structure South Wales steam-coal. It gave off much dust, but the use of tight skips kept the roads clean. The seam was easy to work, and the workmen earned high wages. They showed, however, their usual indifference by refusing to clean the shale from the floor before beginning to fill the coal, and this injured its reputation. Their desire to dictate to the management and the never-ending demands of their paid agitators finally exhausted the company's patience, and the colliery was eventually shut down permanently. If arrangements could have been made for vessels to be always under the staithes, the output would have increased, but this was impossible. The works were cramped for space, and confined by streets, houses, and the harbour. The whole of the *débris* from sinking, from making bottoms, and from driving the long headings—even the ashes from the boilers—had to be removed by lighters. Coal-winding could therefore only proceed while vessels were under the staithes. There was no room for the storage of wagons, so that the position of the colliery on the shores of the harbour was in reality a disadvantage. These and other disadvantages, in addition to the impossible conditions and the bellicose attitude of labour, forced the closure of a colliery on which upwards of £300,000 and an infinite amount of thought and anxiety had been expended.

Coke-making.—An excellent silvery coke from the bituminous coal of the Newcastle (New South Wales) district had been made for upwards of fifty years in beehive coke-ovens. One small beehive plant was erected in the Southern Coalfield in 1891, at which, by crushing the small coal, a superior hard coke was made. The large smelting plants at Broken Hill and others imported the whole of their coke supplies from Germany, the North of England, or from South Wales. When the deposits of lean copper-ores at Mount Lyell (Tasmania) and others were being developed, proposals to use Australian coke led to practical experiments being made which showed that the steam-coal of Illawarra, although higher in ash and in fixed carbon than the bituminous coal of Newcastle, produced a harder coke, cellular and better adapted to withstand the pressures in large furnaces, whilst its ash content was not materially higher than in coke made from Newcastle coal (see Appendix). To make 1 ton of coke at Newcastle, quite 2 tons of coal are used, while from 26 to 27 cwt. of southern coal is only required.

Mount Lyell began the erection of ovens at Port Kembla, and soon after the Broken Hill Proprietary erected a larger plant at South Bulli; South Clifton Colliery erected a plant of beehive ovens, and other smelting and private companies have erected large batteries of ovens near the other collieries. The saving in the cost of coke to the Broken Hill companies must have been very considerable.

It was early found that rectangular ovens that dealt with larger charges, saved time and expense in charging, and enabled the coke to be pushed out by electrical or hydraulic pushes or rams, gave better results than beehive ovens.

Careful consideration was given to the adoption of bye-product ovens, but the proposal was abandoned as unpayable on account of the low yield of tar and ammonium sulphate in the lean southern coals, the great cost of importing (in part due to the excessive tariff) and erecting bye-product plant from Europe, and the additional cost of sending the products to Europe. A modification of the Welsh or Thomas oven gained favour. The first battery of these ovens was erected with side and bottom flues, and measured 21 feet by 4 feet by 5½ feet. Smelting companies soon afterwards erected ovens measuring 30 feet by 2 feet 9 inches by 6 feet, with horizontal side and bottom flues. Other companies adopted larger ovens 30 feet by 6 feet 8 inches by 6½ feet and 30 feet by 8 feet by 5½ feet, some with vertical flues and some without. All the batteries use small coal crushed fine. Eight companies have up to the present erected 602 ovens. With the exception of the beehive plant, all the others use hydraulic, electric, or steam pushes and levellers. One employs a Buchanan compressor and charging-box, in which the duff is pushed into the oven, the coke being quenched by sprayers. In the majority of the plants a portion of the waste-gases from the coke-ovens is used to raise steam or for the generation of electricity required at the mines.

The numerous difficult conditions imposed by wages boards have much increased the already high cost of labour at the ovens. The excessive overtime imposed for work done between noon on Saturday and Monday morning has necessitated alterations of the usual practice of working ovens continuously, and oven charges are now adjusted so as to avoid Saturday afternoon or Sunday drawing. It has been found most suitable to burn for 72 hours. The higher temperature required for 24 hours' burning necessitates the use of a higher quality of firebrick than has yet been made in Australia, the cost of which from Europe would be prohibitive.

The output of the wider coke-ovens is nearly double that of the narrower ovens, which, owing to labour restrictions, cannot obtain the advantages in the arrangement of flues that they possess. The coke can be quenched in the wider ovens, and this avoids the dust and heat that mainly appeals to non-technical tribunals that now fix the rates of wages, and largely contributes to the increased cost besides imposing hampering conditions. With the exception of one battery, the various ovens are charged through three or four openings from large canisters mechanically moved above the ovens that discharge their contents. The doors are raised and lowered by hydraulic power.

In the year 1892 Newcastle produced 12,262 tons and the southern district 5,595 tons of coke; in 1914 Newcastle produced 28,264 and the southern district 276,536 tons, which in 1915 was increased to 333,619 tons.

APPENDIX.

I.—ANALYSIS OF WATER FROM SHAFTS AT SYDNEY HARBOUR COLLIERY.

	Grains per gallon.
Ferrous chloride	45·71
Calcium carbonate	125·16
„ sulphate...	83·09
Magnesium chloride	221·41
Sodium „	971·24

II.—COMPARATIVE ASSAYS OF COKES.

From	Moisture. Per cent.	Volatile hydro-carbon. Per cent.	Fixed carbon. Per cent.	Ash. Per cent.	Sulphur. Per cent.	Specific gravity.
Co-operative Colliery, Newcastle ...	1·87	0·27	87·77	10·45	0·04	1·814
Uuanderra, southern district	0·21	0·15	87·55	11·50	0·45	1·934
Hoods, South Wales (B. Hill, Central)	0·36	0·37	88·86	9·70	0·71	2·032
Hamburg, Germany...	0·35	0·55	88·58	9·20	1·32	1·831

DISCUSSION OF MR. J. IVON GRAHAM'S PAPER ON "THE ORIGIN OF BLACKDAMP." *

MR. A. FAULDS (Vancouver, B.C.) wrote: The prolonged oxidation of the sample of coal from Houldsworth Colliery, Ayrshire, is a very interesting and important experiment. Half a century ago considerable difficulties were experienced in operating the Carnochan and Dalharco coal-areas adjoining Houldsworth Colliery, owing to the oxidation of pyrites in these underground workings, and most particularly in the old abandoned workings. Very considerable and rapid corrosion generally of all cast-iron materials occurred, so much so that for the unwatering of the mine wooden working barrels of beech

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* *Trans. Inst. M.E.*, 1917-1918, vol. lv., page 294.

hooped with brass had to be adopted. The cast-iron plant was short-lived, and the ironwork of the shoes of the colliers' drawers were corroded away in a comparatively short period.

The water from the collieries was taken care of in surface ponds by filtering, etc.; but on one occasion these filtering-ponds burst, allowing the water to escape into the River Doon, and all the fish for several miles down the river were killed. Underground fires of rather a dangerous and costly nature occurred periodically, with loss of life in some cases.

Mr. J. Ivon **Graham** (Doncaster) wrote, in reply: The long oxidation experiment on the sample of coal from Houldsworth Colliery showed that the blackdamp arising from the oxidation of the coal alone never contained more than approximately 5 per cent. of carbon dioxide, whereas analyses of samples taken from behind sand-stoppings in the above-mentioned pit showed in some cases almost 17 per cent. The late Mr. William Smith had always been puzzled by these results. In view of what Mr. Faulds has mentioned concerning the conditions existing in the adjoining coal-areas of Carnochan and Dalharco, it seems very possible that the high percentage of carbon dioxide may have been due largely to the action on carbonates of acid waters—either produced *in situ* by the oxidation of pyrites, or by infiltration from neighbouring districts or old workings.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM APRIL 27TH TO MAY 31ST, 1919, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of		Magnetic character.	Intervals in hours (Greenwich mean time).												
Week.	Month.		0h. to 2h.	2h. to 4h.	4h. to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h.	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
	April		14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
Sun. ...	27	0	43′·5	41′·5	39′·0	38′·0	39′·5	44′·0	47′·5	46′·5	44′·0	43′·0	42′·0	41′·0	42′·5
Mon. ...	28	0	41·5	42·0	40·5	39·5	40·5	44·0	47·0	45·5	43·0	42·5	43·5	43·0	42·5
Tues. ...	29	0	43·0	42·0	41·5	39·5	41·0	45·5	48·5	46·0	43·0	40·0	42·0	42·5	43·0
Wed. ...	30	0	42·0	39·5	39·5	39·5	42·0	46·5	49·5	47·0	44·5	42·0	39·5	41·0	43·5
	May														
Thur. ...	1	0	41·0	41·0	40·0	39·0	40·5	45·0	47·5	46·5	44·5	43·5	43·0	41·5	42·5
Fri. ...	2	2	41·0	45·5	39·5	40·5	39·5	44·5	40·5*	52·5*	48·5*	41·5*	38·5*	40·0*	42·5
Sat. ...	3	2	32·0*	25·0*	40·0*	49·5	52·0	49·0	49·5	49·0	45·5	44·0	43·5*	40·0*	43·0
Sun. ...	4	1	38·0	38·5	40·0	39·5	39·0	42·0	46·5	48·5	47·0	43·0	37·0	37·0	41·5
Mon. ...	5	1	37·5	35·0	36·5	38·5	40·0	45·0	49·0	46·5	43·5	40·0	40·5	39·0	41·0
Tues. ...	6	1	38·0	40·0	39·0	37·5	37·5	40·5	44·5	45·5	43·0	40·5	40·0	40·0	40·5
Wed. ...	7	0	40·5	40·5	39·0	37·5	38·0	41·5	46·0	46·0	45·0	43·0	41·0	40·5	41·5
Thur. ...	8	0	41·0	40·5	39·0	36·5	38·0	42·0	46·0	46·0	44·5	43·0	42·5	41·5	41·5
Fri. ...	9	0	41·5	40·0	37·0	36·5	39·0	44·0	47·0	45·5	44·5	43·5	43·0	41·5	42·0
Sat. ..	10	0	40·0	40·0	41·0	43·0	43·0	47·0	48·0	47·0	45·0	43·5	43·0	42·5	43·5
Sun. ..	11	0	42·0	41·5	40·0	39·0	41·0	45·5	47·0	45·0	43·5	43·5	43·0	42·5	43·0
Mon. ...	12	0	41·5	40·5	39·5	37·5	39·0	45·0	50·5	48·0	43·5	43·0	43·5	42·0	43·0
Tues. ...	13	1	39·0	38·5	42·0	39·0	38·5	45·5	51·5	49·0	44·5	40·5	37·0	37·5	42·0
Wed. ...	14	1	38·5	39·0	39·0	38·5	39·0	46·0	51·0	47·5	44·5	41·0	38·5	39·0	42·0
Thur. ...	15	1	40·0	40·0	41·0	39·0	38·5	43·5	48·0	47·0	44·5	41·5	41·5	42·5	42·5
Fri. ...	16	0	42·0	41·5	37·5	35·0	37·5	44·0	50·5	48·0	44·0	42·5	41·0	41·5	42·0
Sat. ...	17	1	42·0	40·0	38·0	36·5	39·0	46·0	50·0	51·0	47·5	41·5	35·5	37·5	42·0
Sun. ...	18	1	36·5	37·5	39·5	40·0	41·0	48·5	52·0	47·5	43·5	42·0	41·0	41·5	42·5
Mon. ...	19	0	41·5	41·0	38·5	35·0	38·0	46·0	50·0	48·5	44·0	42·0	41·5	38·5	42·0
Tues. ...	20	1	38·0	33·0	33·0	35·0	38·0	44·5	49·0	47·5	44·0	41·0	40·0	41·5	40·5
Wed. ...	21	1	41·0	39·0	36·5	34·0	35·5	43·5	48·0	49·0	46·5	44·0	38·0	37·5	41·0
Thur. ...	22	1	38·5	36·0	38·0	39·5	39·5	43·5	47·5	46·5	43·5	42·0	37·0	37·5	40·5
Fri. ...	23	0	40·5	40·0	38·0	36·5	39·5	44·0	46·0	45·0	42·5	41·0	41·5	42·0	41·5
Sat. ...	24	1	42·5	42·5	45·0	41·5	43·5	47·0	48·0	47·5	42·0	39·0	36·5	39·5	43·0
Sun. ...	25	1	40·0	36·0	37·5	38·0	38·0	43·5	49·0	49·5	45·0	43·0	42·0	41·5	42·0
Mon. ...	26	1	41·0	39·0	37·0	37·0	38·5	44·0	51·0	51·5	48·0	44·0	39·5	39·5	42·5
Tues. ...	27	1	40·5	43·5	44·0	36·0	35·0	41·5	46·5	46·0	42·0	41·0	41·5	41·5	41·5
Wed. ...	28	0	41·5	40·5	37·0	36·0	38·0	42·0	45·5	44·0	42·0	41·0	42·0	42·0	41·0
Thur. ...	29	0	41·5	41·5	40·0	35·5	37·0	43·0	48·5	48·0	43·5	42·0	42·0	42·0	42·0
Fri. ..	30	0	41·5	40·0	37·0	34·5	36·0	41·0	45·5	47·0	43·0	42·0	42·5	42·5	41·0
Sat. ...	31	0	40·5	40·0	40·0	37·0	37·5	43·5	48·0	46·5	43·5	42·0	41·0	41·0	41·5

Diurnal Inequality (*i.e., departure from mean value for day*).

	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.
May, 1918	−0′·7	−1′·0	−1′·3	−2′·2	−3′·2	−4′·4	−5′·5	−5′·3	−3′·9	−1′·1	+2′·5	+5′·3
April, 1919	−1·3	−1·6	−2·2	−2·1	−1·8	−2·2	−3·4	−4·2	−3·3	−1·1	+2·2	+5·1
April, 1918	−1·1	−1·3	−1·4	−2·0	−2·1	−2·7	−4·2	−5·4	−4·8	−2·0	+1·6	+5·1

	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
May, 1918	+6′·5	+6′·8	+4′·8	+3′·2	+1′·7	+0′·4	−0′·3	−0′·4	−0′·4	−0′·2	−0′·3	−0′·5
April, 1919	+6 8	+6·9	+5·4	+3·6	+2·0	+0·6	−0·5	−1·2	−1·7	−2·0	−2·1	−1·8
April, 1918	+7·3	+7·1	+5·4	+3·5	+1·9	+0·5	−0·1	−0·4	−0·8	−1·4	−1·5	−1·3

* Large disturbances during this interval.

Mean Value for Month.

May, 1918.	April, 1919.	April, 1918.
14° 51′·6.	14° 42′·7.	14° 52′·0.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G.M.T.

Character "0" means a day wholly free from any but small disturbances.

" "1" " " part or all of which is moderately or considerably disturbed.

" "2" " " part or all of which is highly disturbed.

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EXPLANATIONS.

The —, at the beginning of a line denotes the repetition of a word or words ollowed by a comma in the preceding entry; and in the case of Names, it includes both the Christian Name and the Surname; or, in the case of the name of any Firm, Association, or Institution, the full name of such Firm, etc.

Discussions are printed in *italics*.

The following contractions are used:—

M. C.—The Midland Counties Institution of Engineers.
M. G.—The Manchester Geological and Mining Society.
M. I.—The Midland Institute of Mining, Civil, and Mechanical Engineers.
N. E.—The North of England Institute of Mining and Mechanical Engineers.
N. S.—The North Staffordshire Institute of Mining Engineers.
S. I.—The Mining Institute of Scotland.
S. S.—The South Staffordshire and Warwickshire Institute of Mining Engineers.

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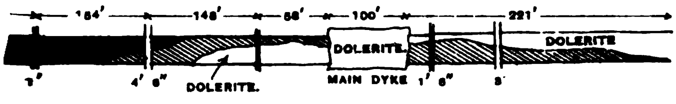
'S OR MASSES ENCOUNTERED IN EXPLORING DRIVES.

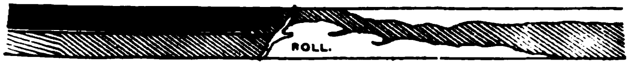
F IG. 3.—SOUTH EXPLORATION DRIVE.

UPPER SEAM.

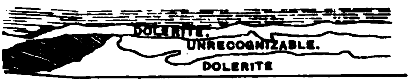


154'
148'
58'
100'
221'
DOLERITE.
DOLERITE
DOLERITE.
MAIN DYKE
1'
4' 6"
1' 6"
8'

FIG. 4.—NEW WINNING, BULLI COLLIERY.



INE AT BULLI COLLIERY (v. FIG. 9).



DOLERITE.
UNRECOGNIZABLE.
DOLERITE

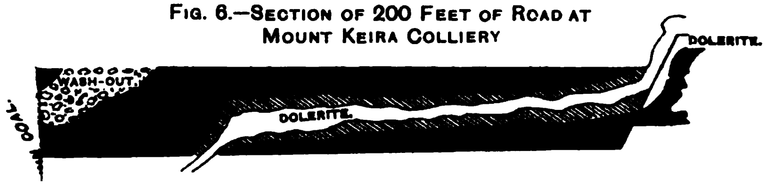
REFERENCES

▨ CINDER

■ COAL

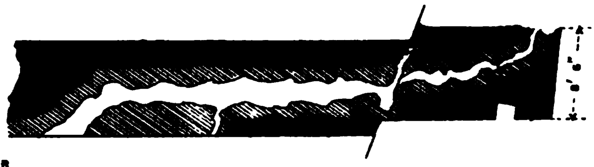
☐ DOLERITE.

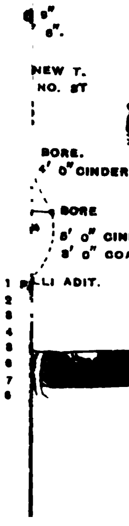
FIG. 6.—SECTION OF 200 FEET OF ROAD AT MOUNT KEIRA COLLIERY



WASH-OUT.
COAL
DOLERITE.
DOLERITE.

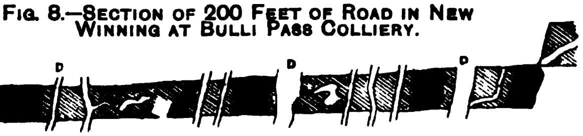
FIG. 7.—SECTION IN AN EXPLORING ROAD.





6"
6".
NEW T.
NO. 8T
BORE.
4' 0" CINDER
BORE
5' 0" CINDER
3' 0" COAL.
LI ADIT.
1
2
3
4
5
6
7
8

FIG. 8.—SECTION OF 200 FEET OF ROAD IN NEW WINNING AT BULLI PASS COLLIERY.



S OR MASSES ENCOUNTERED IN EXPLORING DRIVES.

Fig FIG. 3.—SOUTH EXPLORATION DRIVE.

UPPER SEAM.

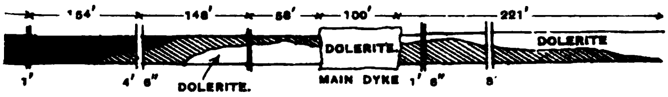
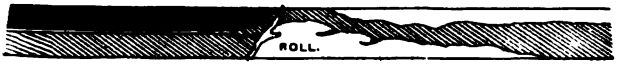
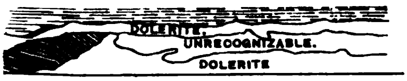

154'
148'
58'
100'
221'
DOLERITE.
DOLERITE
1'
4' 6"
DOLERITE.
MAIN DYKE
1' 6"
8'

FIG. 4.—NEW WINNING, BULLI COLLIERY.



INE AT BULLI COLLIERY (a, FIG. 9).


DOLERITE.
UNRECOGNIZABLE.
DOLERITE

REFERENCES

▨ CINDER

■ COAL

□ DOLERITE.

FIG. 6.—SECTION OF 200 FEET OF ROAD AT MOUNT KEIRA COLLIERY

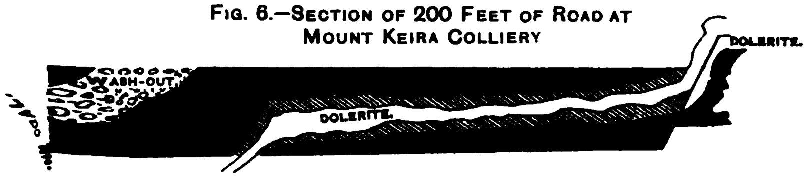
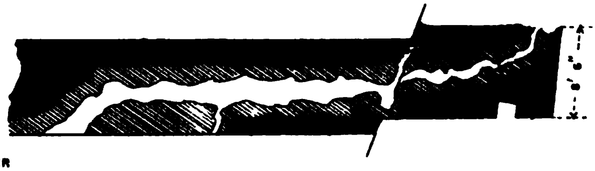
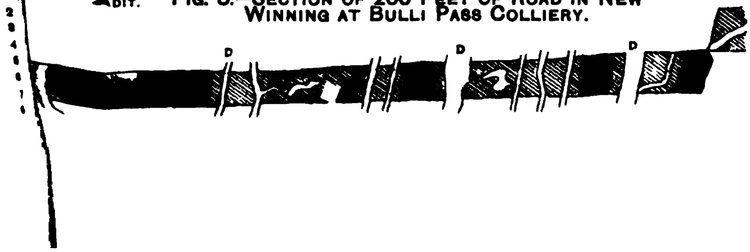

WASH-OUT.
DOLERITE.
DOLERITE.

FIG. 7.—SECTION IN AN EXPLORING ROAD.



9 0"
6"
NEW T.
NO. ST
BORE.
0" CINDER
ORE
0" CINDER
0" COAL.
ADIT.

FIG. 8.—SECTION OF 200 FEET OF ROAD IN NEW WINNING AT BULLI PASS COLLIERY.


1
2
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FIGS. 10 TO 13.—"ROLLS" ENCOUNTERED AT BULLI COLLIERY.

FIG. 10.—SECTION THROUGH *a-b* OF FIG. 11.

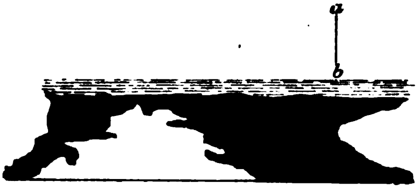


FIG. 11.—PLAN OF A ROLL.

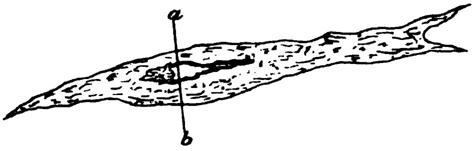


FIG. 12.—SIDE ELEVATION.

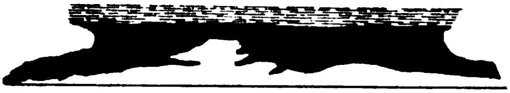
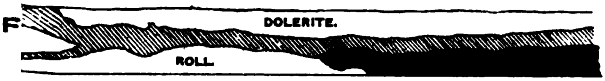
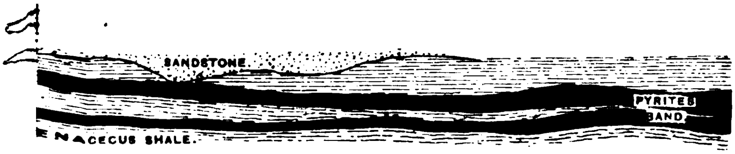


FIG. 13.—SECTION IN BULLI COLLIERY.


DOLERITE.
ROLL.

CTION OF MAIN EAST HEADING AT SYDNEY HARBOUR
SCALES: HORIZONTAL, 200 FEET TO 1 INCH:
TICAL 80 FEET TO 1 INCH.


SANDSTONE.
PYRITES BAND.
ACECUS SHALE.

to 1 Inch. *Vertical Scale, 30 Feet to 1 Inch.*

TRANSACTIONS

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OF

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MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM JAN. 26TH TO MARCH 1ST, 1919, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of		Magnetic character.	Intervals in hours (Greenwich mean time).												
Week.	Month.		0h. to 2h.	2h. to 4h.	4h. to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
	Jan.		14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
Sun. ..	26	0	44′·0	44′·0	44′·5	44′·5	44′·0	46′·5	49′·0	47′·5	45′·5	45′·5	44′·5	43′·0	45′·5
Mon. ...	27	0	44·5	45·0	44·5	44·0	42·5	44·5	47·5	47·0	45·5	45·0	44·5	44·0	45·0
Tues. ..	28	1	43·5	44·5	45·0	44·5	44·5	47·0	49·5	50·0	46·5	44·0	40·5	41·5	45·0
Wed. ...	29	1	40·0	42·0	43·5	43·5	43·5	47·0	49·5	48·0	46·0	45·0	45·0	42·5	44·5
Thur. ...	30	0	44·0	45·0	45·0	44·0	43·5	47·0	50·5	51·0	48·5	46·0	45·0	43·5	46·0
Fri. ...	31	2	43·5	42·5	43·5	43·5	44·0	48·5	50·5	48·0	47·0	36·5*	38·0*	37·0*	43·5
	Feb.														
Sat. ...	1	2	40·5*	48·0*	47·0	47·0	45·5	47·0	49·0	45·5	42·0	43·0	43·0	43·5	45·0
Sun. ...	2	2	44·5	45·0	45·0	46·0	44·5	48·0	50·0	46·5	39·0*	42·0*	41·0	42·0	44·5
Mon. ...	3	1	43·0	47·0	47·5	46·0	46·0	46·5	47·0	46·0	44·5	44·0	41·5	42·5	45·0
Tues. ...	4	1	45·0	46·5	44·5	44·5	42·5	47·0	52·0	48·0	41·5	43·0	42·5	42·0	45·0
Wed. ...	5	1	42·0	44·0	47·5	46·0	45·0	47·5	49·0	45·5	45·0	40·0	44·0	44·5	45·0
Thur. ...	6	1	45·0	45·5	44·0	45·5	48·0	50·0	48·0	46·0	45·0	45·5	42·0	41·5	45·5
Fri. ...	7	0	44·5	44·5	44·5	44·5	45·0	46·5	47·5	46·0	45·0	44·5	44·0	44·5	45·0
Sat. ...	8	0	44·5	43·5	44·0	43·5	44·0	47·0	48·0	46·0	45·0	45·5	44·5	44·5	45·0
Sun. ..	9	0	44·0	44·0	43·5	43·0	44·5	47·0	48·5	47·0	45·5	43·5	41·5	43·0	44·5
Mon. ...	10	0	44·5	45·0	44·0	43·0	43·0	46·0	48·5	47·0	45·0	44·0	43·5	43·5	45·0
Tues. ...	11	0	44·5	45·0	43·5	43·0	42·5	45·0	46·5	46·0	45·0	43·5	43·5	44·0	44·5
Wed. ...	12	0	44·5	44·5	44·0	43·0	42·5	46·0	48·0	45·5	45·5	45·0	44·0	44·0	45·0
Thur. ...	13	2	44·5	44·5	43·5	43·0	45·0	47·0	49·0	50·0	52·0	49·5*	41·5*	38·5*	45·5
Fri. ...	14	2	37·5*	35·0*	40·5	43·0	45·0	47·0	48·0	47·5	42·5*	31·5*	41·5	43·5	42·0
Sat. ...	15	1	45·0	46·0	43·5	42·5	46·0	49·5	49·0	45·5	43·5	43·0	41·5	39·0	44·5
Sun. ...	16	1	41·0	44·5	43·5	44·0	46·5	47·5	47·0	47·0	41·5	44·5	39·5	41·5	44·0
Mon. ...	17	0	43·5	44·0	44·0	45·0	46·5	47·0	46·5	45·0	44·0	42·5	41·5	42·5	44·5
Tues. ...	18	1	43·5	43·5	43·5	44·0	44·0	45·5	47·5	45·0	44·5	43·0	44·0	41·5	44·0
Wed. ...	19	0	43·0	43·0	43·0	43·5	44·5	45·0	46·0	45·5	45·0	44·5	43·0	41·5	44·0
Thur. ...	20	0	41·0	41·0	40·5	42·5	45·5	48·0	48·0	47·0	46·5	44·5	44·0	42·5	44·5
Fri. ...	21	2	35·0	35·0	39·0	40·5	43·5	48·0	50·0	48·5	34·5*	35·0*	40·0*	43·5*	41·0
Sat. ...	22	2	43·0*	41·0	41·5	45·5	47·5	49·5	50·0	48·0	45·5	37·0*	40·0*	37·0*	44·0
Sun. ...	23	2	37·0*	42·5	42·0	45·0	47·0	51·0	50·5	47·5	45·0	37·5	38·5*	39·0*	43·5
Mon. ...	24	1	40·5	41·0	41·0	43·0	44·0	47·5	47·5	46·0	44·5	44·5	45·0	44·5	44·0
Tues. ...	25	0	43·0	42·5	41·5	42·0	43·0	46·0	48·5	46·0	44·0	41·5	45·5	44·5	44·5
Wed. ...	26	0	42·0	41·0	41·0	41·5	43·0	47·0	49·0	46·0	45·0	46·5	45·5	43·5	44·0
Thur. ..	27	1	42·5	40·0	39·0	41·0	43·5	47·5	48·5	47·0	46·0	47·5	48·5	44·0	44·5
Fri.	28	2	40·0*	36·0*	41·5*	48·5*	45·5	46·5	48·5	48·0	43·5	40·0*	42·5*	42·0*	43·5
	March														
Sat. ...	1	2	46·5*	42·0	43·5	43·5	43·5	48·5	51·5	46·0	43·0	34·5*	41·5	43·0	44·0

Diurnal Inequality (i.e., departure from mean value for day).

	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.
February, 1918 ...	−1′·1	−1′·0	−0′·9	−0′·8	−0′·5	−1′·0	−1′·7	−2′·6	−2′·8	−1′·5	+0′·7	+2′·6
January, 1919 ...	−1·2	−0·8	−0·3	−0·4	−0·7	−0·3	−0·1	−0·9	−1·2	−0·1	+1·7	+2·7
January, 1918 ...	−0·9	−0·6	−0·2	+0·5	+0·2	−0·4	−0·9	−1·5	−1·8	−1·6	+0·5	+2·2

	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
February, 1918 ...	+3′·1	+3′·3	+2′·9	+1′·8	+1′·3	+0′·7	+0′·2	−0′·4	−0′·6	−0′·7	−0′·6	−0′·6
January, 1919 ...	+3·2	+3·2	+2·3	+1·7	+0·8	+0·1	−0·4	−1·2	−1·9	−2·3	−2·1	−1·6
January, 1918 ...	+3·1	+3·4	+2·4	+1·2	+0·4	+0·1	−0·2	−0·6	−0·9	−1·4	−1·7	−1·4

* Large disturbances during this interval.

Mean Value for Month.

February, 1918.	January, 1919.	January, 1918.
14° 53′·5.	14° 45′·4.	14° 54′·8.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G.M.T.

Character "0" means a day wholly free from any but small disturbances.

" "1" " " part or all of which is moderately or considerably disturbed.

" "2" " " part or all of which is highly disturbed.

TRANSACTIONS
OF
THE INSTITUTION
OF
MINING ENGINEERS.

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE UNIVERSITY, LEEDS, JANUARY 30TH, 1919.

MR. W. D. LLOYD, PRESIDENT, IN THE CHAIR.

THE PETROGRAPHY OF A SEDIMENTARY ROCK, WITH SPECIAL REFERENCE TO THE CARBONIFEROUS SYSTEM.

BY ALBERT GILLIGAN, D.Sc., B.Sc., F.G.S.; LECTURER IN ECONOMIC GEOLOGY, UNIVERSITY OF LEEDS.

In the work of correlating beds occurring at great distances from each other, palæontology has been, and still is, of first importance. The petrology of sediments can, however, as I hope to show, in and of itself furnish us with information concerning palæogeography which the science of palæontology fails to supply.

It was a most fortunate thing for those of us engaged upon the petrology of sedimentary rocks that such a vast amount of work had been done upon the igneous and metamorphic rocks, in determining their chemical composition, mineralogical constitution and age, and defining the areas where they are found upon the surface of the earth, for without such knowledge at our disposal the investigations now made possible among the sedimentary rocks could not have been usefully carried forward. The reasons for this are obvious when we remember that the original source of all the material now accumulated in our stratified or sedimentary rocks is to be sought in the igneous rocks which have resulted from the cooling and solidification of a molten magma. The most important rock, speaking in a general way, which has yielded mineral matter to be re-formed into such sedimentary rocks as grits, sandstones, limestones, clays, etc., is granite, and a brief outline of the constituents of this rock and its degradation products under the usual conditions may not be out of place.

The essential constituents of granite are quartz and a potash felspar (orthoclase or microcline) and plagioclase. In most cases one or more minerals of the mica, hornblende, or pyroxene group are present, as well as small quantities of what are called "accessory minerals," such as magnetite, zircon, and apatite; more rarely occur garnet, tourmaline, sphene, beryl, topaz, epidote, fluorite, and pyrites. The proportions in which these minerals occur in a typical grey granite of Barre, Vermont, have been determined to be as follows:—

	Per cent.
Microcline	56·8
Orthoclase	2·1
Plagioclase	1·3
Quartz	28·5
Biotite	10·2
Muscovite	0·1
Sphene	0·6
Total	99·6

The granite will give access to dilute acidulated waters along the joints; in time the granite near the surface of the ground will be reduced to a "rotten" condition, and can be broken into fragments in the hand. This friable granite may differ little from the compact rock, all the minerals except those of microscopic size being readily distinguishable. Actually at the surface further weathering may have produced a clay-rock, in which only the minerals other than felspar may be recognized, since the clay is the product of the decomposition of the felspar. It may be said that in general in a moist temperate climate the break-up of a granite mass is brought about by the decomposition of the felspar and the consequent release of the other minerals. It may so happen that the products resulting from such action may not travel far from their original source, and when recompacted form a rock known as "arkose," which scarcely differs at all from a granite in chemical composition, but the mode of aggregation of the mineral particles will be different. As will be shown later, the grits of the Carboniferous System are of this type. If, however, the end products of weathering be transported by water, a sorting will take place, and the fine clayey particles and small thin flakes of mica will be washed away from the coarser materials and be transported farther. So that the river carrying the burden of sediment from a granitic land-mass will be laying down the coarser quartz and felspar grains in one place to form grits later on, and the finer particles of the same minerals in another to form a sandstone; the finest-grained mud-particles are carried farthest and go to form beds of clay or shale, while the lime in solution will supply the calcium carbonate for the formation of limestones.

With this necessarily brief introduction attention will be directed to the particular group of sedimentary rocks, the petrography of which will yield many points of interest to the coal-mining engineer, namely, those forming what is known as the "Carboniferous System." This system furnishes us with most of the main types of sedimentary rocks, including as it does conglomerates, breccias, grits, sandstones, limestones, and clay-rocks, and therefore affording opportunities for our utmost skill in unravelling the problems with which they confront us.

In a paper read before this Society by Mr. G. Blake Walker,* the distribution of land and water in Carboniferous times was dealt with in a most instructive way, and in the discussion,† I spoke of the new light which had been thrown upon this subject by the study of the petrography of the fragmental deposits which make up so large a part of the rocks of the system; and nothing better perhaps can be attempted here than to amplify the remarks made at that time, confining my attention chiefly to Yorkshire and the adjacent counties.

The Carboniferous Period was ushered in by the accumulation in the valleys of the old land-surface of great quantities of scree and talus material, which now compacted forms what is known as the "Basement Conglomerate," which may be seen and examined in many stream-sections in the neighbourhood of Kendal, Kirkby Lonsdale, Sedbergh, and other places in North-West Yorkshire and the Lake District. A detailed petrological examination of these beds is now being conducted, and some important deductions are being made regarding the source of origin of the pebbles and finer-grained fragmental materials of which the beds are composed. One striking fact which has been known for some time is that fragments derived from the Shap Granite mass occur plentifully in the beds exposed in a splendid section along the side of Wasdale Beck, near Shap Wells Hotel. The unmistakeable large pink felspars characteristic of the Shap Granite (which can be examined in many of the buildings in Leeds) are found in some abundance, and reveal the fact that this granite, which, when cooled and solidified in the period just preceding the Carboniferous, was covered by some thousands of feet of rock, had been uncovered and exposed to weathering, supplying by its waste much of the sediments for the formation of these Carboniferous beds. From the polygenetic conglomerate of this age on Roman Fell, near Appleby, pebbles of gneiss and schist have been recorded, and their origin assigned to a northerly source. So we have some indication of the conditions under which the basement beds were formed and the source whence the material was derived. The conglomerate is succeeded by the Carboniferous Limestone and Yoredale Beds, and these may be regarded as a single phase, the Carboniferous Limestone representing the accumulation of calcareous material in comparatively clear and shallow water, while the Yoredales represent the landward phase. The thick beds of relatively pure limestone in Derbyshire are replaced at successively lower and lower horizons, as it is traced northwards by beds of sandy and muddy detritus. These detrital beds are in the form of wedges, with the feather-edge to the south and the broad end to the north, and this can be quite clearly interpreted as due to the proximity of the shore-line of a land-mass which rose to the north, the drainage of which supplied the detritus. The shallow-water origin of the limestone is evident from the types of organisms, the hard parts of which now form so great a proportion of the rock, such as crinoids, corals, and mollusks, which are shallow-water types; and also by the current-bedding traceable in some of the beds, as, for instance, at Gordale, and, if further proof were needed, the presence of a coal-seam with its seat-earth, interbedded with the limestones, at Meals Bank Quarry, Ingleton. A continental shelf fringing a land which was undergoing elevation would furnish the conditions necessary for the succession of the beds here described, and I regard the incoming of the detrital material of the Yoredale rocks as evidence of the increasing relief of the land-mass to the north, due to uplift, and the consequent rejuvenescence of the old rivers, which were thus enabled to sweep seaward the rotted rock which had accumulated during the period when the land lay at a low level.

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* "The Areas and Deposition of the Coalfields of Western Europe," *Trans. Inst. M. E.*, 1917-1918, vol. liv., page 77.

† *Ibid.*, page 90.

The Millstone Grit Series, which was one of the earliest of sedimentary rocks to receive attention from a petrological standpoint by the late Dr. Sorby, supplies us with reliable information regarding the precise area where this great land-mass was situated, and a more detailed account of the investigations which I have carried out, together with the conclusions at which I have arrived, will be helpful to the understanding not only of the history of this series, but also that of the succeeding Coal-Measures.

The Millstone Grit Series may be described as consisting of coarse conglomerates and felspathic grits, alternating with beds of shale, with quite subordinate impure limestones and coal-seams. So like granite does the fresh grit-rock appear, with its fresh felspars showing glistening cleavage faces, that it has oftentimes been mistaken for a granite. A chemical analysis fails to distinguish it from some types of that rock, but a petrological examination at once reveals the fact that the minerals present in it, although of similar types to those in a granite, show evidences of attrition by being rolled along in water, and are held together by a matrix, thus differing from the mode in which they occur in a granite. It is, as a matter of fact, a rock resulting from the accumulation of the minerals of weathered granites and kindred rocks brought down by rivers and spread out in the form of a delta over the continental shelf upon which the Carboniferous Limestone and Yoredale rocks had been formed. Evidence of its deltaic origin can be found in a comparison of the succession of strata of which it is made up with sections of beds passed through in borings of some of our large modern deltas, such as those of the Mississippi or the Ganges and Brahmapootra. That the delta was comparable in size with these modern deltas is easily recognized when the area over which the series once extended is examined upon a map, and this connotes the fact that the rivers forming the delta of the Millstone Grit must at least have equalled in size these giant rivers of to-day.

In studying the details of the petrology of the rocks, recourse must be had to the examination of as many exposed sections as possible, and also the cores brought up from the numerous boreholes which have been put down into this series of rocks in search of a water-supply, and specimens of pebbles collected, examined macroscopically and microscopically, and comparisons instituted with rocks occurring in areas likely to have yielded them. Such work has yielded most interesting results. The first pebbles to attract one's attention are those of quartz, the " hummer stones " of the quarrymen. These are so plentiful in some of the beds as to warrant the term " conglomerate " being used for the rock, and this is especially the case in the lowest and topmost beds of the series called respectively the " Kinderscout Grit " and the " Rough Rock." The common shape of these pebbles is ellipsoidal, but elongated sphenoid forms occur frequently, and this shape alone is at once suggestive of their having been derived from a metamorphic rock such as a coarse-grained gneiss, in which the mechanical deformation to which the rock has been subjected tends to produce such forms. A microscopical examination supports this conclusion—effects of pressure, sometimes to the extent of mylonitization, being evident in them all. Pebbles of pink felspar occur abundantly in the coarse beds, and are usually quite fresh to the outside, showing that they were detached from their parent rock by mechanical agencies, such as rapid changes of temperature, and hurried along to be embedded in the sediments before weathering by chemical agencies affected them.

At one time it was thought that pebbles consisting of these two minerals combined were rare, but such is not really the case, as I have found them in abundance in practically all the coarse beds of the series. Pebbles of these three types are by far the most frequent, but pebbles of the following types have also been obtained, although they are extremely rare:—Granites (different varieties), quartz and felspar porphyries, gneiss, mica-schist, quartz-schist, quartzite, silicified limestone, grit, sandstone, and shale.

It is necessary also to examine the material of finer grade in the grits and sandstones as well as the shales, and, in order to do this, samples were taken from the different horizons in many areas, and after crushing were separated by sieving into grades of varying degrees of fineness down to less than $\frac{1}{80}$ inch, and each separation was examined independently. The results showed that quartz and felspar of the same types as the larger pebbles, together with some mica, made up the great bulk, and even the finest material was simply rock-flour consisting of the same minerals, with the addition of small quantities of the rarer heavy minerals, such as garnet, zircon, tourmaline, rutile, magnetite, ilmenite, monazite, etc. The separations of these rarer minerals are exceedingly beautiful when examined under the microscope, both on account of the perfection of crystal form shown by some of them, such as zircon, or the delicate colours of others, such as the garnets, tourmaline, rutile, and monazite.

On summing up the evidence of the complete examination, it may be definitely stated that only in what is now the North of Scotland and in Scandinavia are rocks to be found which could have supplied the mineral species and rock types enumerated above, and the enormous volume of material in the grit beds demands a land-mass of continental dimensions.

The coarser detritus in the Millstone Grit, when contrasted with the finer in the Yoredales, points conclusively to the progressive elevation of the land, giving increased slope and so greater carrying powers to the rivers draining the area. Observations of the current-bedding in the grit show that the distributaries of the great river flowing over the delta and bringing with them their burden of sediment entered Yorkshire from the north-east; so that it would appear that there was a main-trunk river flowing southward between what are now Scotland and Scandinavia, receiving tributaries on either bank, and that it debouched possibly at one stage somewhere near what is now the north-east coast of England. The uplift of the land to the north and the depression of the sea-floor to the south, with the hinge-line somewhere about latitude 57° N., is quite in agreement with some of the modern ideas relating to the isostatic equilibrium which must necessarily exist between two adjacent areas, one of which is being unloaded by denudation and the other loaded by deposition; but one cannot do more than suggest such a connexion on this occasion.

Coming now to the Coal-Measures, it has been found that a similar method of investigation to that described for the Millstone Grit affords evidence of the derivation of the minerals of the sandstones from precisely similar types of rocks, the only difference being that the material is of finer grade and contains relatively less felspar and more abundant mica than does that of the Millstone Grit. Occasionally, however, coarse grits and even conglomerates occur in the Coal-Measures similar in all respects to the beds found in the underlying Millstone Grit. The proportion of clay-rocks to grits and sandstone is, however, much higher in the Coal-Measures than in the Millstone Grit, and these clay-rocks demand attention. When considering the products of weathering of a granite, it was pointed out that when decomposition of the felspar took place, due to carbonated waters removing the alkaline constituent, a hydrated silicate of alumina—kaolin—was formed, which under favourable conditions may accumulate to form valuable beds of china-clay. It might have been argued—indeed, it has been so—that the clay-rocks of the Carboniferous Series represented very largely the results of such reaction. An examination of the shales of the Millstone Grit Series shows that they are composed of the finely-comminuted particles of quartz, felspar, and mica; the felspar is, however, the least abundant. The accessory mineral, zircon, is also extremely abundant in most of those examined, whilst garnet, tourmaline, and rutile are also usually present. Hutchings,* as a result of a careful investigation into the mineral constituents and chemical composition of Coal-Measure shales, has shown that they consist very largely of a fine rock-flour of quartz and felspar, together with a large proportion of secondary mica (sericite) formed by the decomposition of orthoclase felspar *in situ*, while the proportion of kaolin is very small. He also says: "I have always maintained, and still maintain the more strongly the more I examine them, that the clays and shales of the Carboniferous beds represent the waste of granitic and gneissic areas practically 'pure and simple.'" . . . Kaolinization of the felspars in the rocks of the old land-mass did not, therefore, take place to any great extent; and the extreme freshness of the felspars throughout the clastic deposits of the Upper Carboniferous rocks may be interpreted as pointing to the fact that the granites, gneisses, etc., from which the felspar was derived were not decomposed by carbonated waters, but that the rocks disintegrated by mechanical means, such as rapid changes of temperature or by the action of ice. Of these alternatives, the former can be shown to have been the most probable agent, and is the one which I have adopted. There is a further inference that the atmosphere of Upper Carboniferous times was not more highly charged with carbon dioxide than is that existing at present; in fact, the evidence leads one to think that it was probably somewhat deficient in carbon dioxide, since so large a quantity had probably been locked up during the formation of the limestone of the Lower Carboniferous System.

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* Hutchings, *Geol. Mag.*, 1890, pages 264-316; 1894, pages 36-45.

This evidence from the petrological side is in agreement with the more recent conclusions arrived at from the study of both the animal and the vegetable life which flourished during the period.

It becomes easily understood why the sedimentary rocks of the Coal-Measures are similar to those of the Millstone Grit Series, but of finer grade. The old land-mass was being base-levelled; the rivers in consequence draining from it would be more sluggish, and could only carry the finer-grained material to the delta. The distributaries would become more numerous, and in consequence the deposits more irregular.

So far I have endeavoured to show how the petrography of the sedimentary rocks enables us to piece together the palæogeography of the time when it was formed. The methods here briefly outlined are, however, capable of much more than this. Correlation of coal-seams is a subject with which the mining engineer is familiar, and he knows how difficult it is oftentimes to be sure that correct inferences have been drawn from the available data. The occurrence of marine bands at definite horizons and extending over wide areas has proved of great value in elucidating some of the problems of this nature. Petrological science has, however, shown that it can be of much service for the purposes of correlation when efficiently applied, although it certainly has greater limitations than palæontology, and cannot as yet be applied over such wide areas.

It becomes especially difficult in the case of such a suite of rocks as those forming the Coal-Measures, for we know how often it happens that the measures represented in one place by a succession of thin beds of shale, sandstone, and coal may in a contiguous area be represented by a thick bed of sandstone. The sandstones are impersistent, being merely wedges or lenticles, and are often very restricted in both horizontal and vertical extent. In the hand-specimens many of these sandstones look exactly alike, but when subjected to examination in thin sections under the microscope, and mechanical and mineralogical tests are applied, striking differences are frequently apparent; and although the work along these lines upon which I am engaged has not yet proceeded far enough for me to make any definite pronouncement, yet it is sufficiently clear that useful results may be expected. Such investigations on the sandstones in the Coal-Measures of the Central Valley of Scotland by Dr. T. O. Bosworth* have shown that distinctive differences exist in their heavy mineral content, and he suggests that by obtaining a sufficient number of accurate determinations of this kind, and by taking account of the current-bedding and the thickening and thinning of a bed, it would be possible to subdivide the measures into a number of great lens-shaped or wedge-shaped bodies of sediment, and to express the results in the form of a map which would be helpful in explaining the lateral changes and the distribution of the coals. Admirable work of a similar nature has been done among rocks newer than the Coal-Measures by Dr. H. H. Thomas and Prof. P. G. H. Boswell, but the work is still in its infancy, and the tediousness of the processes involved perhaps accounts for the paucity of labourers in this field of research.

Finally, I would like to point out how such studies may be of use in the explorations for coal in our concealed eastern coalfield which are now being carried out, and will become increasingly important in the near future. The test-borings will be made through the cover of Triassic and Permian rocks to the Coal-Measures, and it may be necessary to decide at some stage in the processes whether the rock encountered belongs to the Coal-Measures or the newer rocks, and in the absence of fossils the only guide will be petrology. Can the question be decided by such means? The answer cannot be definitely in the affirmative, but there is every probability of it being so if a careful and critical examination of the material brought up from the bore be made at sufficiently close intervals. Too frequently the identification is left in the hands of the borer, who may or may not have the necessary knowledge to decide such cases, and whose nomenclature is, to say the least, not always intelligible to the geologist.

In any case, it is hoped that provision will be made for obtaining the most precise and accurate information concerning the measures passed through in any future explorations, and so materially help those who are seeking to extend our knowledge of the sedimentary rocks, and to learn how to interpret the underground geology in Eastern Yorkshire.

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* *Proc. Geol. Assoc.*, 1913, part 2, pages 57-61.

The PRESIDENT (Mr. W. D. Lloyd): The geological and petrological aspects of the paper form a subject which is new to most of us, but it is interesting to hear how the petrologist is able to confirm or corroborate the evidence of the palæontologist in connexion with boreholes, and in that way be most useful to the mining engineer. Dr. Gilligan has put before us very clearly the way in which the Millstone Grit and Coal-Measures were probably laid down.

Mr. C. H. MERIVALE (Middleton): Dr. Gilligan has combated the theory that the ancient land in the central part of England, known as "St. George's Land," might have supplied the material for the Millstone Grit, and shown that the belt of country referred to was not large enough to have produced the series. Have the boreholes put down recently not far from that area proved that the high belt was made of the older rock?

Dr. GILLIGAN (University of Leeds): They have: the older rock shows through in places—at Charnwood, for instance—and the newer rocks bedded against it successively overlap each other. The geological results actually confirm the petrological theory.

Prof. P. F. KENDALL (Leeds): I think the lesson we may learn from Dr. Gilligan's investigations is the importance of trying to visualize the conditions under which the Carboniferous rocks were deposited. The Coal-Measures present an infinity of problems, both to the geologist and to the practical miner, and some of those problems concern them both. We have, for example, interruptions of the coal-seams, due to a variety of causes—faults, wash-outs, and the mere thinning out of seams. Upon a correct interpretation of these phenomena will depend our predictions, which is a matter that concerns the mining engineer, and we shall never obtain that correct interpretation unless we quite clearly understand and visualize the general conditions under which the Carboniferous rocks, and the Coal-Measures particularly, were deposited. The conception of the whole series as a vast deltaic suite, laid down in shallow water—sometimes salt and sometimes fresh—at the mouth of a great river pouring in from the north-east or some northerly direction, is the clue to the solution of a very large number of these problems. When a big river spreads out, by what are termed "distributaries," over a delta, as we know to be the case with the Ganges, the Brahmapootra, and the Nile, it varies its course from time to time. During flood-time the river is in too great a hurry to go through all its windings, and goes straight ahead. When the flood subsides, it may lapse back into its old winding channel, or it may have a new and straighter channel cut for it, or a regular network of such channels. These are frequent episodes in the history of most rivers of such low gradient that they produce a great flat delta, and they are the regular phenomena observed. It is one of the great problems of the civil engineer to prevent rivers from following this course. Vast sums of money have been spent in the United States in the endeavour to curb and control the Mississippi. China has expended vast labour in the endeavour to control the Hoang Ho, the river which is known as "China's Sorrow," because of its unfortunate habit of bursting its banks and short-circuiting in this direction or in that, resulting in great destruction of property, and loss of human life by tens of thousands at a time. In view of this habit in present-day rivers, we must be prepared to see the effects of such evil ways in the rivers of the Coal-Measure period. The time when the area upon which a river was spreading its delta had attained a temporary condition of stability was the time when coal was formed—when the deltaic expanse was in a condition of permanent marsh. If the river should sweep over that area in time of flood, it would rip out the marshy deposits which have become the coal-seams of to-day; and so we have the phenomena of "wash-outs," the splitting of coal-seams, and so forth. This, therefore, is the lesson of the paper.

I have a particular interest in Dr. Gilligan's exposition, because it helps me further to understand not the regular, humdrum, every-day behaviour of a river, but its occasional paroxysms of destroying energy, when the Coal-Measure rivers would cut out the forming coal-seams, leaving those distressing vacuities which are such a loss and annoyance to the colliery interest in Yorkshire and in other coalfields of the world.

Mr. E. W. **Thirkell** (Aldwarke Main): The value of a subject like this to mining engineers depends on whether its teachings find application in his ordinary work. The usual way of finding things out about the rocks in the past has been by means of the fossils. To-day we have had introduced a new method, which we are told will enable us to discover things concerning rocks which hitherto we could not. The new science of petrology should therefore be of great value to the mining engineer.

Mr. F. **Oxley** (Sheffield): Would Dr. Gilligan give some explanation as to how the beds of shale between the various members of the Millstone Grit have been formed?

Dr. **Gilligan**: The explanation of the phenomenon of the succession of grits, sandstones, and shales is largely one connected with the velocity and grade of the river. The shales of the Millstone Grit and the Coal-Measures are to a very large extent nothing more nor less than the comminuted material which we get in the coarse beds. They differ in their composition very little indeed, and so it is a question of grade rather than anything else. There is a higher percentage of mica in these beds than in the ordinary grits and sandstones, and this is somewhat anamalous, as the specific gravity of mica is greater than that of felspar and quartz; but, on account of its flat shape, mica is more readily floated. The sorting of mica from the quartz and the felspar is thus due to its shape, and not to its specific gravity. While the river would first lay down the heavy material forming a coarse conglomerate, the finer grade of material would be carried farther, and the finest grade of all, together with a certain proportion of mica, would float out still farther; so that the river was really depositing all grades at one time. We must also remember that land drained by the river was not stationary, but was being tilted up, and, when a geologically " sudden " tilt was introduced, the river would have a steeper gradient. The material laid down in the upper part of its course would be swept out, and so we might possibly get a shale, succeeded by a sandstone, and on the top of that a conglomerate. That would be the succession of things, if one could visualize the history of a river, and as revealed by borings in deltas forming at the present time.

The **President**: One of the slides shown by the author helps us to form some conception of the slowness of deposition of the formations, and the quantity of material brought down by the rivers. The slide showed that the Danube, in ordinary times, brought down something like 11,000 tons of material a day, but in flood-time the quantity was 2,500,000 tons. I have no doubt that some of the members present have had experience of the boulders that occur under the Beeston Seam. Can Dr. Gilligan give us any idea as to where they came from, and also how they were deposited? Roughly speaking, they are about as big as a man's head, and weigh from 30 to 50 pounds. They are more or less isolated, and are only met with occasionally in the fireclay under the Beeston Seam.

Dr. **Gilligan**: The amount of material brought down by a river increases tremendously in flood-time; one may put it that the carrying power of a river increases as the sixth power of its velocity. Thus, if the velocity is doubled, its transporting power is increased 64 times; if its velocity is trebled, its transporting power is increased 729 times; and so on. The volume of water is, of course, greatly increased in flood-time. Further, in flood-time a river cuts into the alluvium which it has previously deposited in its upper reaches, and carries it forward. With regard to the boulders, which sometimes occur in the coal-seams themselves, as well as in the seat-earth, that is a question into which I intend to look more closely in the near future. But there is this to be said: these boulders are of somewhat similar types to those which I have found in the Millstone Grit. They are often quartzites and granites. Now we do not find in Yorkshire or in any adjacent area rocks of the types occurring in the Coal-Measures. The only explanation which I think is in agreement with the actual conditions is that the pebbles were caught up by vegetation and floated into the position where they are now found. We know that seaweed, attaching itself to a pebble on the sea-shore, will enable that pebble to be transported when the tide comes in. I exclude ice from my explanation, because I do not think that ice played any part whatever in that area in the period with which I have been dealing. Of course, my explanation is only a tentative one; I have no absolute proof of its correctness, and it is only a suggestion which occurred to me in looking into the question of the origin of similar boulders in the Millstone Grit. I have come across a perfectly good granite at Skelmanthorpe right in the coal, and I can offer no other explanation than that it was rafted in in some way by vegetation.

The further discussion of the paper was adjourned.

THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,
Held at the University College, Nottingham, January 18th, 1919.

Mr. H. EUSTACE MITTON, President, in the Chair.

PRESIDENTIAL ADDRESS.

By H. EUSTACE MITTON.

In addressing you to-day, it is my desire to avoid any controversial matter, and merely to bring before you some subject of importance, with the hope that it may appeal to you as being worthy of further consideration.

I propose to discuss the investigation of inferior fuels of a non-caking character from the point of view of using them to greater advantage.

The experience of the past seems to afford us little guidance in the problems which have been brought about by the great change that has taken place in this country since we entered upon the conflict in 1914.

The mining industry of this country has before it questions of the weightiest and gravest character. Mining engineers are faced with difficulties and problems which will tax their abilities to the utmost if in the struggle the industry is to maintain a foremost place in the new business world.

No organization or research-work will give the desired result, unless the employer and employee co-operate and pull together for the common end. The mining engineer and the workman must each welcome new processes, and realize the altered conditions, so as to produce the maximum output with the minimum amount of manual labour.

The conservation of our coal supply, by using all the coal won in the mine, and by getting a greater value out of our coal when used for heating in the domestic hearth, or for generating power in the boiler, is one of the foremost and most urgent matters requiring the mining engineer's attention. The Government has given a lead in this important matter: special reports are published and certain lines indicated as to the best means of producing power more cheaply with the inferior coal through the installation of electric-power stations in different areas of the country, interlinked and feeding as one vast unit for all.

The question of the installation of electric-power stations, as foreshadowed by the Reconstruction Committee's Report, is open to considerable divergence of opinion. The modern colliery to-day generally derives a large amount of its power from an electric source. The winding-engine is the key of the lock, and every mining engineer knows the success of the undertaking depends on the key always being in perfect order.

The proposal now before the country is to supply cheaper power by putting down large electric-supply stations, and, in order to ensure success, these stations will require large markets for this power over wide areas. In considering the colliery companies as consumers, the present method of generating their own current by using the exhaust-steam from winding-engines will have to be superseded. In order to do this, the mining engineer will have to be satisfied that when he wants the electric power it will be forthcoming in the quantity he requires. The bump-load of the winding-engine is very great, and the matter of supplying collieries from these power stations will have to be very fully gone into. The power company will have to generate its electricity at the lowest cost, and in order to do this will have to use the cheapest fuel and work on the most economical lines, so as to have a large supply with a full demand.

It is important that trade and industry, perseverance, and human push and energy should be absolutely free from Government control, except in the earlier stages, when trade will have to change from the manufacture of the sword to the making of peace instruments. During this period a certain amount of control is necessary, otherwise the struggle for materials and plants urgently required to assist in the future working of our mines and in the development of the areas under which the future power of the world now lies dormant would lead to confusion and chaos.

One of the most important subjects before the mining engineer to-day is the conservation of our coal supply, and the utilization of our coal resources to their utmost.

Coal is divided into two classes, namely, coking coals and non-coking coals. With regard to the latter, there are many coals which produce a soft and brittle coke. These, although really coking coals, cannot be classed with the coking coals that produce a firm coke. In order to distinguish between these coals, it is customary for the expert who determines the coking value of any coal to describe under this heading only the real coking coal that produces a metallurgical coke.

In this district there are coal-seams which vary as to their coking properties in different areas. It is well known that beyond a certain line in Derbyshire the coal from the different seams, unless blended, is of a non-coking character, so far as the production of a metallurgical coke is concerned. It is with the coal from these seams that the mining engineer has to consider how best it can be treated in order to obtain a greater value per ton and greater efficiency for the nation. The greater value per ton would enable the coal-owner to pay a higher rate for getting the coal. The greater efficiency would produce power to the consumer at a lower rate, and would conserve the coal, as more products would be obtained from it, and all the coal would be used, instead of a percentage being left in the mine.

Let us consider the method of getting the coal in this district, and its distribution. The coal is generally got by holing under the seam; in many cases the floor is hard, and the holing takes place in the coal. The process of holing produces small coal, and as the filling into the tram is done either by fork or by hand, a proportion of coal is left behind, and is thrown into the "waste" with the dirt. At the present moment the question of altering the system of filling the coal out of the mine by these means, which leaves behind a certain percentage of small, is being considered in this country, and the introduction of shovel-filling in districts where the fork or riddle has been used before is being pressed.

On the surface the coal is sorted over the screens, and is divided into many qualities and sizes.

In dealing with coal below a certain size and quality, the mining engineer is faced with a serious difficulty. For the coal above these finer sizes, there is always a good market for the finest fuel in the world. It is the slack and inferior fuel, the "tailings" of the screens, which present a difficulty, and it is in dealing with this class of fuel that either a profit or a loss per ton to the owner is realized.

It has been the custom up to the present at collieries owning non-coking coals to depend on the cycle of trade. Many hundreds of thousands of tons of slack and inferior fuel have been dumped on the ground to keep the wheels going in order to dispose of 72 per cent. of the output. Trade revives and the dumps are then picked up.

It is to this slack and inferior fuel that I wish to direct the mining engineer's attention. Is it possible to use this class of fuel to destruction and to recover certain products from the same, so as to make the enterprise a commercial success? Taking the fuel available in this district which comes within this category, we have (1) the fine slack with a heavy percentage of dirt, (2) the bats and "jacks," and (3) the cannel coal. If these coals are taken from the market in their raw state and treated as proposed, what is the prospect of success?

FINE SLACK FROM TOP HARD SEAM.

This fuel, from tests made, gives the following results:—

Distillation Results.

Ammonium sulphate	27 to 33 pounds per ton.
Gas	12,000 to 13,000 cubic feet per ton, of a calorific power of 500 British thermal units.
Oil	35 to 40 gallons per ton.

Producer Results.

Ammonium sulphate	About 45 pounds per ton.
Gas	70,000 cubic feet per ton of coal going to the retorts, of a calorific power of 130 British thermal units.

Assuming that 30 per cent. of the producer-gas is used to heat the retorts, whilst the remainder is mixed with the gas from the distillation, then for every ton of coal distilled there should be available about 47,000 cubic feet of gas, of a calorific value of about 220 British thermal units, for steam-raising.

"JACKS" OR BRANCH COAL.

This coal is an inferior cannel, and is found in the Top Hard Seam. It varies very much in quality, some districts where this coal is obtained producing a fuel *very* stoney, and not so rich in product as others. The yield of oil from this class of fuel in distillation process varies with the quality of the coal from 16 to 40 gallons per ton. The residue produces an inferior brittle coke of about 60 per cent. of coal treated.

CANNEL.

The cannel coal is found in small quantities in a seam peculiar to itself and in connexion with the Tupton Seam, the bright coal in the top portion of this seam in certain areas being cannel of very good quality.

The yield of oil in distillation gives as high as 50 gallons per ton, and the residue about 60 per cent. of fuel suitable for domestic purposes and equal to coalite.

TONNAGE AVAILABLE.

The results obtained from recent borings indicate that during the next few years large collieries will be established in South Yorkshire and East Nottinghamshire. Bearing in mind the importance of raising to the surface all coal wrought in the mine, the prospect of a large tonnage of small coal from the seam is probable. The development of this seam will probably produce "jacks" or "branch" coal.

The Tupton Seam has recently been proved in Nottinghamshire with a good section of rich cannel, and the Silkstone recently proved in Derbyshire has also proved a good section of cannel.

The prospect of a good supply of these fuels being established, and the preliminary research-work having shown the products which can be obtained from them, it is now for the mining engineer to devise the best means for treating these coals so as to obtain from them the utmost value, and in treating them to do so in a way to leave a margin of profit for the capital invested and to allow of good wages being paid for getting, treating, and handling the coal.

The best known method of recovering the oil up to the present is by means of retorts with low temperature, whereby the coal is partly carbonized and the oil abstracted from it. The temperature varies from 400° to 700° Cent., and in many cases steam is employed.

Various types of retorts are in existence, and many difficulties present themselves in connexion therewith, especially in the mechanical parts of the retort. In recovering the ammonium sulphate the producer gives the best result. It is considered by some that the low-temperature retort, worked in conjunction with the producer, may give the best commercial result, the oil being first recovered, the residue used in the producer to recover the ammonium sulphate, and the surplus gas used for generating steam.

In order to ensure success, the following essentials are necessary:—The retort must be so constructed as to allow of a through-put of sufficient tonnage to repay the capital outlay and depreciation charges on the retort. As the capital outlay is heavy, an output of at least 7 tons per twenty-four hours should be secured. The depreciation charges also are likely to be heavy, as the retorts are yet only in their infancy, and in addition to wear and tear provision should be made for replacing the retorts as the experience gained produces better designs. The labour involved in charging and discharging is an important item, and should be reduced to a minimum, every mechanical means possible being employed for this work.

The question of dealing with the products is another important factor; allowing for the recovery of oil, ammonium sulphate, and waste-gas only, the question of an outlet for these products is a matter for careful consideration.

OIL.

The oil produced will probably be found to be of no use for lubricating purposes, owing to its low viscosity. It will probably contain a high percentage of paraffin wax, and will quickly solidify. An arrangement should be made with large oil companies who have central refineries to take the crude oil, and the matter of cracking should be a separate undertaking, and be dealt with at the refinery in the district. These refineries could be established at different centres to collect the oil from distillation plants and borings, and be the distribution centre or clearing-house for all crude oil.

AMMONIUM SULPHATE.

The extended use of this as a fertilizer is a sufficient guarantee for its production, which will depend on the fluctuations of the market, and how cheaply it can be produced.

WASTE-GAS.

The volume of gas will probably be large, and an outlet for it is very important. The volume will no doubt be greatly in excess of the amount required at collieries, especially where the exhaust-steam is being used for generating electricity. The most attractive form for using this gas would be in conjunction with large electric-power plants for the distribution of electric power, as foreshadowed in the report of the Reconstruction Committee. The question of cost on the carriage of fuel to the works plays an important part, and as the power stations, if established in this country, will be by the great waterways, it is essential for the success of treatment of inferior fuels that the coal-owner and producer of electric power should work together.

RESEARCH.

The Government has formed a committee for advising on research in this country, and a sum of money has been allocated for prosecuting this work. It is well known that investigation on a small scale is often incapable of ascertaining the true result, and it is desirable therefore that investigation on a large scale should be conducted. This is applicable to the subject of my Address, and it is the evident intention of the Government to stir up the interest of the industries to establish associations of their own to expand largely the research-work of this country. Where it is necessary, assistance from the Government will doubtless be granted, with certain conditions, but the funds will only be granted to large industries like coal-mining for the purpose of establishing research associations that are to be carried on largely by the industry itself.

The importance of the Government Committee lies in the prevention of overlapping, and in protection against investigation of any particular subject peculiar to any individual company. For instance, where a firm has a secret process of manufacture, its rights should be protected.

In conclusion, the object of this Address is to bring these important matters prominently before you, in the hope that further interest may be aroused, and that funds may be found for the purpose of carrying on such investigation on a larger scale than in the past. It rests with the coal-owner to provide the capital, and the mining engineer to consider carefully all the advantages and disadvantages. Provided that the inferior fuels are treated at a reasonable cost, and the coal used to destruction, there is a reasonable prospect of a greater value being obtained from these fuels. The subject is one that I heartily commend to the members of the various Institutes for careful thought, and to the coal-owners of this country for further investigation, on a much larger scale than has been the case in the past.

The mining industry has now set up a Research Committee, constituted of representatives of each district, under the direction of the Mining Association of Great Britain. It is greatly to be desired that this Committee will work jointly with The Institution of Mining Engineers, and act as one body in this important matter.

It is to the interest of the coal-owner to provide the necessary funds for carrying on the work essential for full and thorough investigation, and it is for the members of the Institution to endeavour, as far as lies in their power, to assist by using all the influence they have and by rendering all the assistance they can to further the work by their united efforts.

DISCUSSION OF PROF. F. W. HARDWICK'S PAPER ON "THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION."*

The **PRESIDENT** (Mr. H. Eustace Mitton): The subject as dealt with by Prof. Hardwick differs very much from the subject as dealt with by Mr. Berriman. It appears to me that Prof. Hardwick has approached the question with the idea that all mining students desire to become general managers, consulting engineers, or agents; but what we have to bear in mind also is the position of those who wish only to obtain a mine manager's certificate. Prof. Hardwick does not deal fully with that difference.

Many men to-day acting as under-managers are fully qualified, so far as practical knowledge goes, to hold the position of manager, and are debarred from doing so because the examination is too severe an ordeal for them at their time of life. I commend for your consideration an alteration in the present system, and for a higher standard to be initiated for those desirous of reaching the highest positions in the profession.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 94.

Prof. Hardwick touches on the establishment of a central information bureau; but is such a bureau necessary? Ought not the Institutions and Colleges in this country to supply the need?

The age at which a young man should enter the profession and his course of study are worthy of full consideration. In the Nottingham district and in Durham and Northumberland it has been the practice for many years for those who can afford to pay for their education to be articled to well-known mining engineers connected with large undertakings. Many distinguished mining men have followed this course, and have done honour to the profession. Many colliery companies have an arrangement whereby sons of their employees who cannot afford to pay a premium have the privilege of going through the various departments. This has also been the means of producing good men well known in the mining world.

We are now asked to advance further and to consider the acquisition of practical with theoretical knowledge. The "sandwich system," as Prof. Hardwick calls it, appeals to me strongly. I think that the method frequently adopted in the past is quite wrong, and that no student can pursue his studies efficiently and properly when, by the nature of the conditions, he has to do so spasmodically. If he worked six months at the colliery and got to know what a coal-mine is, next went for six months to a College, and then came back to the mine, that would be most helpful, and this is a point to which I hope full consideration will be given in the ensuing discussion, which I suggest shall be adjourned until the meeting to be held on May 3rd.

Mr. WILLIAM MAURICE (Sheffield): Prof. Hardwick's paper interests me, and when I read it I immediately endeavoured to obtain a copy of the publication of the Engineering Training Organization; but, after consulting various possible and impossible sources of information, I failed to discover anyone who knew anything about the organization in question. We are all thinking what we can do to make "reconstruction" a reality, and not merely something to talk about, and this trifling difficulty of mine raises a point which, although not directly germane to the discussion, is not, I think, wholly irrelevant, namely: why is it so extraordinarily difficult to obtain information about anything in England? Time after time I have been confronted with this problem. If special technical information is wanted, it has to be laboriously and patiently extracted by reading many books, which may, but usually do not, contain what is required. If commercial data is wanted, and a Chamber of Commerce is applied to, they don't know; if it is of such a nature that a trades directory ought to supply it, it usually doesn't; if a reference to a foreign publication is called for, the particular number one wants is usually missing; in short, concerning data of all kinds and which all classes of people require, the labour of finding it is appalling.

Prof. Hardwick's paper is itself a recognition of this undoubted fact. Parents want to know how their sons can become mining engineers, and up to now they do not know where to look for the information. In due course, as the result of Prof. Hardwick's efforts, this difficulty will be solved. But if we are ever to modify the national tendency towards muddle, we must see that the information when collected is not left where ordinary folk cannot find it. Every public library to-day is full of dirty and more or less useless books, the influence of which is mainly narcotic. So far as they succeed in "taking tired people to the Islands of the Blest," it is good; but surely something more could be done to improve the taste of library users! Why not make a more extended use of libraries? Why should they not become the recognized means of supplying any kind of information that intelligent citizens require? Why should they not become official clearing-houses for information, and all bureaux, technical and otherwise, which have been or are being established for specific purposes, be linked up, so that anyone may go to the nearest library and either be told directly what he wants to know or precisely who can tell him?

Information is sought in the paper on points of detail, as, for example, the best preparation for the Surveyor's Certificate. But are we really satisfied either that the foundation of a mining-engineering training is being properly laid, or that the subsequent courses of study are adequately adapted to the times? The paper seems to indicate that the Institution of Civil Engineers finally settled the proper preparation for an engineering life about 15 years ago. I have been unable—once more—to find a copy of the report, but one may fairly ask whether any scheme which was drawn up 15 years ago remains the best after the whole world of thought has been turned upside down?

Mining engineers who are destined to have charge of collieries are responsible for a greater number of workers than the members of any other profession or industry. In the course of their duties, they are brought into close contact with labour under conditions which afford constant opportunities for the interchange of views and opinions. Whether in charge of small or large mines, the manager is in a position of influence in his district, and the possibilities for good or ill are enormous. From the first day on which a young man is entrusted with responsible control, his principal business is not with machines but with men! The curricula of the schools provides a sort of technical education which will assist him in utilizing the forces of nature to the best advantage. What is being done to enable him to get the best out of the extraordinarily complex living forces with which he will have to work? What is being done to give him a wise and trained outlook over the immense social possibilities which will confront him? What kind of help is he getting that will facilitate the judicious handling of the labour problems which he will meet from the first to the last day of his active life? I am aware that a little has been attempted, for some of the Universities where mining is taught include engineering economics in their degree courses. Also, some of the same Universities have courses in social science. But I should like to ask: to what extent are such subjects recognized as essential parts of a mining engineer's training, and whether there is actually any mining syllabus which includes the study of social science? As a *viva-voce* examiner for colliery-managers' certificates, I must have questioned many hundreds of candidates; but I am unable to call to mind anywhere near 1 per cent. of them who appeared to know anything whatever of the evolution of industry, of wage systems, of labour problems, of the history or constitution of trade unions, of the interdependence of individual interests, of housing questions, of social or even personal hygiene, or of any other of the essentials of a civic education. It is a commonplace that few students know how to study. They get a treatise on mining, plod at it, memorize rules and formulæ, and when examination time comes fervently hope they won't be asked something that wasn't in the book!

Why are they not taught psychology? Psychology ceased to be a department of philosophy some years ago. It is now just as much a science as physics or chemistry, and certainly not less important for those whose principal business is with men. Through the study of dynamic psychology the mining student would be informed as to how we learn and think, and what leads people to feel and act as they do. On the lower grounds he would be able to recognize malingerers and humbugs of all sorts with the trained acuteness of a Dr. Collie. He would use his newly-acquired faculty of psycho-analysis for the recognition of human motives in his everyday life. He would find industrial difficulties easier to handle, because causes would stand out clearer. His cultivated tendency to analyse motives would save him from innumerable difficulties and annoyances, and, in so far as such a training became general, there would be a greater approach towards sincerity and truth in the national life. As his training progressed, he would develop an appreciation of social motives and group activities, and thus get himself on solid ground for the rational understanding of social ethics.

of Commerce is applied to, they don't know; if it is of such a nature that a trades directory ought to supply it, it usually doesn't; if a reference to a foreign publication is called for, the particular number one wants is usually missing; in short, concerning data of all kinds and which all classes of people require, the labour of finding it is appalling.

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But, as a preliminary to the advanced study of psychology, and, indeed, as a preliminary to the specialized study of anything, he should be taught the art of thinking. Why do students not receive direct instruction on the best ways of utilizing their own energy, on the relation between body and mind, on the laws of mental efficiency, on the value of interest, on the art of analysis, on logic and truth, and so forth?

If these branches of learning are of such great practical value as to induce hundreds of thousands of people of all ages to pay for special tuition in them, why are they not taught in every school in the land? There may be excellent reasons why these subjects should not be taught—I am not an educational expert—and I shall be very glad to hear what the objections may be. In any case, we must have a wider diffusion of essential knowledge, otherwise all talk of reconstruction is mere spume.

Improved educational methods are a fundamental part of the problem of reconstruction, and, by reason of the vast influence which they are in a position to exert, none ought to be more deeply interested in its progress than mining engineers. We have not done everything when we have said "intensified production." Probably we have not even begun. If reconstruction means anything more than money, it represents an attempt to realize a social ideal based on freedom. In this sense it has been said to be the nation's memorial to those who have laboured, fought, and died for it; and if the will to go forward is strong enough to prevail, it will be the noblest memorial ever conceived by the mind of man. But there is a direct conflict of ideas involved, and therefore it is impossible to expect that the whole nation will pull one way. The conflict would have infinitely less effect on the welfare of the community if a greater proportion of its members were socially educated. Wherefore, the best we can do for those who are to follow us is to take care that they receive such courses of instruction as will not only make them capable engineers, but wise and skilful leaders of the people amongst whom they must live and work.

The further discussion of the paper was adjourned.

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,

HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER, JANUARY 14TH, 1919.

MR. A. J. A. ORCHARD, PRESIDENT, IN THE CHAIR.

THE SEARCH FOR PETROLEUM IN DERBYSHIRE NOW IN PROGRESS.

BY THEODORE SINGTON.

Introduction.—The Derbyshire Coalfield, in which the search for petroleum is now being made, is a portion of the Yorkshire-Derbyshire-Nottingham Coalfield, which extends from Bradford and Leeds on the north to Derby and Nottingham on the south, a total length of 63 miles. Throughout the entire distance this coalfield is bounded on the east by a Permian Magnesian Limestone escarpment, stretching across the country like a rampart, and on the west by the still bolder and higher moors of the Pennine Chain, formed of Millstone Grit, Yoredale Shales, and Mountain Limestone.

The portion of the coalfield in which the search for oil is being made extends from a few miles south of Sheffield to Codnor Park (Fig. 1, Plate I.), 4 miles south-east of Alfreton, a total length of nearly 20 miles, and about a third of the Midland Coalfield in a north-and-south direction. This area, with an average width of about 8 to 9 miles, consists of Middle and Lower Coal-Measures. The higher Coal-Measures occur below the Magnesian Limestone further to the east; they dip to the east and rise to the west, the strike being approximately north and south (Fig. 2, Plate I.). The Millstone Grit, the shales, and limestones extend below the Coal-Measures. The strata including the coal-seams are tilted at a low angle, becoming steeper near the Pennine Chain, and crop out generally parallel to it, so that the gannister beds occur on the west and the higher coal-seams on the east. These are the rocks in which the search for oil is to be made.

The Middle Coal-Measures have been ascertained to be about 2,500 feet in depth and the Lower Coal-Measures about 1,000 feet; and as the boreholes are to be sunk to a depth of 4,000 feet, some of them will pierce the Millstone Grit, the shales, and the limestone. The whole area south of Sheffield is dotted over with collieries, many working and others abandoned or worked out, whilst a whole range of collieries have been sunk through the Magnesian Limestone into the underlying higher coal-seams. The gannister beds are also worked to the west near the Pennine Chain, so that the boreholes are not likely to explore ground not now reasonably well known.

An important structural feature of the area selected for the search is an anticline, subsidiary to the great anticline forming the Pennine Chain. It commences near Holmesfield and extends to Unstone in a west-to-east direction for 3½ miles; it then turns to the south-east for 13 miles, and disappears under the Magnesian Limestone near Kedsby, a few miles from Mansfield. Even during a few days' ramble evidence of this anticline can be noted to a limited extent by rock-exposures, in small quarries, in rock-cuttings along roads, and so on; whilst a more detailed exploration of the country would probably yield considerable evidence of its existence: the contours of the ground in many places are obviously due to it, but our main knowledge is derived from colliery workings. There can be no doubt that originally all the coal-seams extended over this arch or anticline, but most of them have been weathered away and crop out on both sides. Two of them, however, the Kilburn and the Alton coal-seams, are unbroken right over the anticline, and are now being worked in shallow collieries. It may also be assumed that the gannister beds extend across the anticline at a great depth.

Oil experts when exploring new localities always look out for anticlines such as the one occurring in North Derbyshire, as experience abroad has shown that they form suitable gathering grounds, assuming, of course, that oil in quantity occurs in the vicinity. Broadly, the whole of the North Derbyshire Coalfield through which the anticline extends, and in which the boreholes are situated, is an undulating plateau about 500 feet above sea-level, with shallow valleys down to 250 feet, and a few small areas just exceeding 600 feet. There are a number of faults which, if oil existed, would influence its distribution; they would also have provided ready channels for the escape and loss of oil which might have been formed and accumulated among the faulted rocks geological ages ago. Seven sites for boreholes have been selected: work was started at one of them on October 14th, 1918, and the plant on another was well in hand when I went over the ground about the middle of November.

The First Borehole.—Taking them from north to south, the first borehole is at Ridgeway, a rural village not yet turned into a colliery town, 5 miles south-east of Sheffield and 2½ miles north-west of Eckington, and about 400 feet above sea-level. The derrick will be a prominent landmark, as the ground falls away rapidly to the west, south, and east. Nothing had yet been done on this site when I was there in November. There are numerous collieries east, north-east, and south-east of this borehole, but none to the west, as the site is on the Lower Coal-Measures about 3½ miles north of the anticline; the bore may, therefore, be expected to pierce the gannister coal-seams, the Millstone Grit, the shales, and the upper portion of the Mountain Limestone. The coal-seams of the Middle Coal-Measures, the Silkstone, Sheffield or Black Shale Coal, the Manor Coal, and all those above them, will be missed. There appear to be no faults of great magnitude in the surrounding country.

The Second Borehole is at Foxstones, close to the mining town of Eckington. In November, 1918, only some plant was on the ground. The site, which is the lowest of the seven, is a level field on the north side of the colliery railway that passes through Foxstones Wood, about 200 feet above sea-level, and is in the Middle Coal-Measures. The Renishaw Park Collieries are within three-eighths of a mile on the eastern side of the site, several old coal-pits are in the vicinity, and the Horuthorpe Colliery is within three-quarters of a mile. A fault just north of the site cuts off this area from that pierced by the Ridgeway borehole. The site is 3½ miles due east of Unstone, where the anticline turns to the south-east. The borehole will pierce the Manor and Silkstone coal-seams, and will then go through the same ground as that through which the hole at Ridgeway will pass. Except possibly some portion of the Lower Coal-Measures, the whole of the ground through which the first and second boreholes will pass is known from colliery workings.

The Third Borehole is at Brimington, a small colliery town 2 miles north-east of Chesterfield, and is the one at which the plant was nearing completion when I visited the site in November, 1918. It is situated in a flat field fronting the road and extending south of the town, close to or on the crown of the anticline, and about 430 feet above sea-level. The fall of the ground both to the west and to the east distinctly suggests the arch. There are several collieries in the surrounding country. The borehole will pass through the coal-seams which extend over the anticline, and if there should be any oil below, both this and the borehole further south should tap it, or yield evidence of its existence by the escape of gas, which, when there is any, tends to accumulate at the crown of the anticline. The direct result of the anticline is to bring the Lower Coal-Measures to the surface of the ground, forming, so to say, an island among the Middle Coal-Measures about 5 miles long by 1 mile wide. The borehole is in the centre of this island, and will pass through rocks similar to those which the first borehole will pierce.

The Fourth Borehole is situated in the rural village of Heath, 4½ miles south-east of Chesterfield and 500 feet above sea-level; but nothing had been done on this site when I was there in November. It is on or close to the crown of the anticline, about 1½ miles from the Magnesian Limestone escarpment on the east; the ground drops rapidly to the east, no less than 250 feet within a mile showing the slope of the anticline and the dip of the Coal-Measure rocks towards and below the Permian Limestone. This slope, which commences at the village, forms a deep, broad, conspicuous valley, on the opposite side of which the Magnesian Limestone escarpment rises like a range of hills. There are a number of collieries in the vicinity, including Gapwell Colliery, which is sunk through the Magnesian Limestone, and many old shafts. This borehole will pass through a portion of the Middle Coal-Measures, the Lower Coal-Measures, the Millstone Grit, and presumably a portion of the Mountain Limestone. There are faults between it and the boreholes north and south of it, so that if it should tap an oil-containing area, it would be one not affected by the other boreholes.

The Fifth Borehole is completely in the open country at Hardstoft, 6½ miles south-east of Chesterfield, in a field abutting on the main road from Chesterfield to Mansfield. This is the borehole on which work was started about the middle of October, 1918, and is being sunk at the rate of 20 feet per day, so that it may now be 1,500 feet down if no accidents or delays have occurred. The site is an extremely prominent one, and is over 600 feet above sea-level. The ground falls away rapidly east and west to 400 feet, and also north and south, so that the derrick, which is about 90 feet in height, is a very conspicuous landmark. The crown of the anticline lies 2 miles to the east, and the Magnesian Limestone escarpment, about a mile to the east, is strikingly prominent. There are several important collieries in the district, west, north, and south, including the Pilsley and the Hardwick Collieries, so that there are ample opportunities, if oil should occur below in quantity and under pressure, for it to give evidence of its existence. The rocks this borehole will explore are very similar to those through which the fourth borehole will pass.

The Sixth Borehole is situated a mile east of Alfreton Station, on level ground a little south of the main road to Mansfield. When I was there in November, a start was being made in the erection of workmen's dwellings and with excavation for the water reservoir. This and the seventh site, 3 miles to the south, are of interest, as they have evidently been selected to explore the ground where 70 years ago a pocket of rock-oil was tapped during a search for coal. This borehole, also in the Middle Coal-Measures, is 500 feet above sea-level. There are many collieries in the immediate vicinity and numerous faults, which isolate the area to be explored from those explored by boreholes north and south of it. As the anticline is a distance of 5½ miles to the east, the area tapped is not affected by it. The rocks which will be pierced by this borehole will be similar to those through which the fifth and fourth holes will pass.

The Seventh Borehole is in the Golden Valley, near Codnor Park and the Jessop Monument, 3 miles south-east of Alfreton. Work had not commenced during my visit in November. The site is 400 feet above sea-level, and is close to the old Riddings Mine from which rock-oil was obtained many years ago. The surrounding area, 50 to 60 square miles in extent, has been cut up by a network of faults, most of which are broadly parallel to the anticline and the Pennine Chain. This borehole, in the Middle Coal-Measures, is 7 miles from the point where the anticline disappears under the Magnesian Limestone; the ground which it will explore will be practically similar to that through which the fifth and sixth boreholes will pass. The coal-seams adjacent to this site are the Lower Hard Coal and the Soft Coal; there are a large number of collieries in the vicinity, more than twenty old shafts, and the Butterley Park Collieries; if there be an oil accumulation below, there have been ample opportunities for it to have given evidence of its existence.

It is important to note the distances between these seven sites, as it has been a complaint abroad that boreholes are placed too near each other, causing loss of oil, waste of capital, and injury to the oilfields. The distances are as follows:—

	Miles.
From the first borehole to the second	3
„ second „ „ third	3¼
„ third „ „ fourth...	4⅝
„ fourth „ „ fifth	2¾
„ fifth „ „ sixth	4¼
„ sixth „ „ seventh	3

These distances are more than ample; moreover, as already stated, faults cut up the country, so to say, into compartments; and even if oil in quantity were tapped by each of the seven boreholes, not one could interfere with any other.

Between the anticline and the Pennine Chain there must obviously be a syncline, and it is remarkable that no borehole is to be sunk to explore it—at least, none has been announced.

Plant.—The plant required for each of the seven boreholes may be briefly summarized as follows:—Directly over the borehole is a derrick, constructed of ironwork, about 20 feet square at the base, tapering upwards for 80 or 90 feet, and consisting of an upright at each corner, with horizontal and diagonal ties and struts. At the top is a strong timber stage, on which several pulleys are fixed. This stage is reached by a ladder fixed to one side of the derrick, which is based on a foundation of timber logs. Round the base of the derrick are lean-to sheds and an engine-house enclosed with corrugated sheet-iron, accommodating the mechanical working parts. Adjoining the engine-house are two portable boilers. A reservoir for water is excavated near the derrick—say 50 feet by 25 feet and several feet in depth—the excavated material being formed into an embankment around it. On each site are erected for the working staff two or three wooden dwellings of framings 8 or 9 feet square, all bolted together and roofed with felt, and containing glazed windows in suitable places. Obviously the whole of this plant can be readily carted to the site, erected, taken down, and removed to another place. A water-supply from local water companies is arranged for, also coal from the nearest colliery. Work is carried on continuously day and night by means of two shifts, each working twelve hours. The borehole has to be lined with iron tubing both to keep out water, if any should be met with, and to keep in oil if any should be discovered. The boring is done by means of a ram weighing possibly 1½ to 2 tons, which is continuously raised and dropped 2 feet, thus subjecting the rock to shattering blows. When 5 feet or so of rock has been crushed, the broken material is flushed with water and a hollow iron casting known as a " baler " is dropped into the borehole. This baler has a perforated bottom provided with a movable plug, so that it fills with the flushed *débris*, and when it is raised the plug closes the opening and prevents any from escaping. The material raised gives some indication of the nature of the rock which is being pierced, but not to the extent and reliability of a core.

The ram is a composite structure of several parts, and occasionally a breakage may occur, causing great difficulty and loss of time, as work cannot be continued until the broken part has been recovered and made good.

What are the Prospects of Discovering Oil?—We now reach the question: Why has the Derbyshire Coalfield been selected for the search for oil? It is reasonable to assume that the ground most likely to yield encouraging results has been selected for the first attempt. There would appear to be two reasons: (1) the actual discovery of rock-oil, or oil products, and (2) the anticline, which experience abroad has shown to be a suitable gathering-ground or reservoir, if there should be any oil near it.

During 1847 Mr. James Oakes of the Alfreton Ironworks bored for coal at the Riddings Colliery, known as the New Deep Pit, at Pye Bridge, near to the borehole in the Golden Valley, when a pocket of rock-oil was tapped and plant for distilling it was erected by Mr. James Young, who afterwards founded the Scottish oil-shale industry in Midlothian. Both lighting and lubricating oils were produced, and from the residue the first candles of paraffin-wax were made. About 300 gallons of oil a day were obtained for about fifteen months, when the supply gradually fell off, and within two years it ceased. Since then no attempt has been made to search for oil. Within the last four decades oil and water have been pumped from the in-bye workings into the shaft sump, lifted to the surface, and run into settling-tanks, from which the water was drained, the oil being then run into barrels. After the abandonment of pumping, oil was obtained by skimming directly from the surface of the standing water in the pit.

The mine was closed down in 1888. It is quite possible that some oil would be found in the abandoned mine at the present time, but not, of course, in paying quantity. Mr. Young expressed the opinion that this oil-supply was produced from coal subjected to the distilling effect of moderate heat; but, so far as I am aware, no detailed examination of the surrounding and higher rocks was made at the time to ascertain the source from which the oil came, which dribbled into the coal-workings. It is just as likely to have come from a layer of shale or porous sandstone above the coal-seams, containing matter suitable for conversion into oil, as from the coal-seams themselves.

Twenty tons of coal subjected to the distilling effect of moderate heat, as suggested by Mr. Young, should yield 1 ton (or 7½ barrels of 42 gallons) of rock-oil, the coal residue being, of course, left *in situ*. This would presumably, if found, be readily detected, as it must differ essentially from ordinary coal. If extensive accumulations of rock-oil should be discovered by means of the boreholes, such as would repay the cost of the search, vast quantities of such coal residuum should exist, and ought to have been discovered in the very numerous workings of the Yorkshire-Derbyshire-Nottingham Coalfield; but so far as I am aware no such remains have been seen, or are on record. It may be suggested that as there has been a vast denudation of Coal-Measure rocks and coal-seams, such residuum deposits may have been entirely swept away without leaving a trace, but that seems scarcely probable. The absence in quantity of any such altered coal is strong ground for assuming that no oil-deposits in paying quantity have been formed from coal-seams.

The rock contents other than coal-seams of all the formations in the locality of the seven boreholes from the top of the Permians to the base of the Mountain Limestone are so well known that it may be safely asserted that no great oil-accumulations have been formed from them. This opinion will obviously also apply to the Lancashire and Staffordshire Coalfields, which were once portions of the Yorkshire-Derbyshire-Nottingham Coalfield, but were cut off by the formation of the Pennine Chain and the erosion of the Coal-Measure rocks extending over it. It is reasonable, therefore, to assume that the search now being made will have no successful result. If such a pocket of rock-oil as was found 70 years ago were surrounded by impervious rock, the oil formed would be preserved until the opening-out of coal-workings at a lower level enabled it to drain into the shaft-sump. The oil searchers now at work, on the other hand, may have been induced to bore in the hope that this outburst of oil came from an accumulation far below, forced upwards by gas or water pressure. It appears to me that there can be no ground for such a supposition; if a considerable store of oil existed below under pressure, the large number of faults in the district would have provided ample means for its escape geological ages ago; moreover, the coal-workings of the last fifty years would have provided facilities for evidence to show itself of the existence of oil at a great depth; but no additional indications of the presence of oil are on record—at least, not within my knowledge.

With regard to the heat which Mr. Young considered necessary to distil oil from coal-seams, there can only be two possible sources—(1) the friction extended over long periods of time resulting from the faulting of the rocks, and (2) the pressure which resulted in the upheaval of the Pennine Chain and the formation of the anticline. The colliery in which the oil-accumulation was found 70 years ago is surrounded by faults. It is reasonable to assume that this oil-accumulation in the old Riddings Mine is not the only one in Derbyshire; others may have been formed, of which some may yet remain to be discovered; whilst others may have escaped along outcrops and faults. Rock-oil has a tendency to give off gas, and to break up into products of varying specific gravity; the lighter portions would escape one after another, until only a residue of grease or lubricating matter would be left. Several such deposits have been found in coal-workings; they may be considered to be the remains of oil-accumulations, the lighter portions of which have escaped. A chemical examination of such a grease deposit would necessarily lead to the conclusion that it was directly associated with oil, whilst the quantity of the grease would give a clue to the original quantity of the oil, the lighter portions of which have been lost.

But such small oil-deposits are not what are being sought for in these seven boreholes. Twelve months ago it was proposed to spend £500,000 on the search for oil in Great Britain; the amount has since been doubled. During 1913, the last peace year, the value of petroleum imported into this country was 5¼d. per gallon. Assuming a profit of 1½d. per gallon, an oil-reservoir would have to be tapped containing no less than 160,000,000 gallons, a third of our imports during that year, merely to refund the amount proposed to be spent in the search. It appears to me that there is not the slightest probability of such a store being found, either in Derbyshire or anywhere else in this country. Assuming that moderate heat suffices to distil oil from suitable rock-material, and that the conditions occur necessary for oil-storage and preservation, then local conditions in Derbyshire evidently suffice to produce isolated pockets of oil, but nothing beyond that. If oil had been produced on a large scale and preserved below, we should have found evidence of its existence many years ago by the escape of gas and of oil under pressure in coal-workings, and along outcrops and faults.

With regard to the anticline, the rocks in Derbyshire were originally deposited in horizontal layers; assuming one or more contained material suitable for conversion into rock-oil, and that conditions existed to transform it into oil, it is obvious that the oil would be so diffused throughout porous strata that it could not be collected. For oil to collect in quantity, special conditions are necessary. The oil-containing rocks should be tilted; beds of unconsolidated sand, porous sandstone, or possibly limestone should occur in convenient positions; an impervious capping of clay, hard limestone, or water-logged rock must cover the area, so as to close in and preserve the oil-bearing deposit; whilst the rocks below should contain water with a tendency to rise and compress the oil.

As already stated, oil tends to produce gas, and if gas in quantity should be formed within a space closed in above and below, pressure would develop. If, then, the rocks are tilted, or compressed into anticlines and troughs, the gas would accumulate at the crown of the anticline, the oil along the slopes and the water in the synclines. If there should be no water, oil might also occur in the synclines. In Derbyshire, therefore, some of the boreholes should have been located along the syncline. The occurrence of natural gas is not necessarily an indication of petroleum: methane may occur in many varieties of rock, or sulphuretted hydrogen may result from the action of water on the sulphur contents of some varieties of rock; but it does not follow that this is an indication of the existence of oil, as many rocks may contain sulphur variously combined. An extensive accumulation of petroleum should produce a proportionately large quantity of gas; if the latter whilst subject to pressure should be tapped by a borehole or colliery working, it should escape in such quantity that the existence of petroleum below in paying quantity could be readily inferred.

An occasional or limited escape of gas is of no consequence. None of the outcrops, faults, or colliery workings of Derbyshire have yielded an escape of gas that indicated the presence of petroleum in the rocks to be explored by the seven boreholes, and it may be safely asserted, I think, that none will be found. It is important to note the difference between the formation of crude petroleum and the concentration in commercial quantity; but what has been already stated on this point will probably suffice to enable the members to understand the difference.

It is not necessary to describe the special features of oil-producing areas abroad, as they are so well known; it must be evident, however, that there is no similarity whatever between the districts from which we obtain our oil imports and the country between Sheffield and Codnor Park in which the seven boreholes are situated. We shall know before next autumn whether the opinion outlined above is sound or not, as all the seven boreholes will then have reached their full depth.

Prof. W. Boyd Dawkins, F.R.S. (Manchester): I entirely accept the courageous conclusions of the author. From my own knowledge of the district, and from a comparison of it with oil-producing regions abroad, I am of opinion that the rocks of this district are so well known, and contrast so greatly when compared with those where mineral oil is found in great quantity elsewhere, that there is no ground for the conclusion that they form a practical oilfield. The Coal-Measures of Yorkshire and Derbyshire are riddled with innumerable workings, and it is common knowledge that petroleum is often found in quantities to be measured by a teaspoon rather than a bucket. I know of hundreds of cases of the occurrence of petroleum, resins, and pitch in the Coal-Measures. The presence of petroleum in small quantities in the workings is really the measure of the amount that can be obtained from the same strata continued to great depths and not yet worked.

We also know the Millstone Grit below the Coal-Measures in the district, and the Yoredales below the latter can be studied in the Pennines, as well as the Carboniferous Limestone below the Yoredales, while the Silurian rocks at the bottom have also been minutely described, where they form the surface in Charnwood Forest, and round Ingleborough in the Lake Country, and in Wales. Petroleum occurs in the Carboniferous Limestone, as well as in the Coal-Measures, in the chambers of fossil shells, and in other cavities in the rocks. In the former, also, an elastic indiarubber-like hydrocarbon—elaterite—occurs at Windy Knoll, near Castleton, in Derbyshire. In none of these strata, ranging in this district to a depth of more than 5,000 feet, are there any indications of petroleum in paying quantities.

The borings have apparently been placed on anticlines on the chance of getting mineral oil that usually in oilfields is forced up from the synclinal areas by subterranean water, and occupies the highest portions of the folded rocks. All that can be said is that the choice of the site is good on the assumption that payable mineral oils exist in the rocks. There is, of course, no other relation between petroleum and anticlines. For these reasons, it is not likely, in my opinion, that petroleum in paying quantities will be found in this district.

My scepticism as to the success of the venture is shared largely by mining engineers who know the British rocks. I have not heard of any competent English geologist having had his opinion asked on the matter. It almost looks as if the locality had been fixed by petroleum experts acquainted with other areas, but not sound guides in dealing with the rocks in this particular district.

Having studied the question of petroleum in Australia and America, having met with it in minute quantities in the search for the Coal-Measures in the South-Eastern Coalfields, at Netherfield, near Hastings, where it is present in the Kimmeridge Shale, and elsewhere, I feel it my duty to lay the results of my experience before the members of this Society.

Mr. JOHN GERRARD (Worsley): We are in a coalfield that is very similar to that where the search for oil is taking place, and local men would certainly be very much surprised if a party of American borers were to come and establish borings between Burnley and Accrington, Accrington and Blackburn, and Blackburn and Bolton. Yet in those areas there are thick beds of black-looking shales that are easily split up and appear superficially to be very oily. Within the last two years a gentleman engaged in extracting oil from peat thought it might be well to examine some of these thick beds of shale found in the Lower Coal-Measures of Lancashire. A number of samples were obtained and tested, but the results were not satisfactory. These small percolations of petroleum are to be found in Lancashire, and I particularly remember one that occurred about the year 1870 at the St. Helens Colliery. There was a fair quantity of the stuff, which became a great nuisance on the roads, and the manager thought it might be used for lubricating purposes. He took the trouble to collect it, and it was used for some weeks, but was found to be unsatisfactory. I have known of two similar percolations of petroleum in the Wigan district, also in East Lancashire, but nothing at all to compare with the quantities of oil obtained on the American Continent, in Canada, Persia, and in other oilfields.

Mr. F. G. Percival (Victoria University, Manchester): In South America and the West Indies, where I have had some experience of prospecting for oil, the prospector requires some evidence that oil is present in the district before he troubles to investigate the structure of the area. That evidence consists of leaks of gas or oil on the surface of the ground, the presence of pitch, and occasionally mud volcanoes caused by the gas bubbling up through the muddy strata. Commonly associated with oil are gypsum and brine, although the reason for this association is doubtful. All or some of these indications should be present before the prospector troubles to look for an anticline, or, better still, a dome, which is an anticline tilted down at each end. In the Derbyshire area under consideration there does not appear to have been a single indication of oil of any real value. The prospectors appear to have relied solely on the structure of the district, because, although the oil-" show " at Riddings Colliery was a fairly large pocket, it was from the Middle Coal-Measures. None of the reports I have seen stated that it came along a fault, but I understand it is said that it did come from a fault. The originators of the scheme do not appear to attach any importance to that " show," and that is borne out by the fact that they do not hope to strike oil except at a depth of between 2,000 and 4,000 feet. The base of the Coal-Measures should be reached at somewhat over a thousand feet in the area where the first boring was put, and if they are down anywhere near 1,500 feet that should be already below the Coal-Measures. The only evidence of oil in the Carboniferous Limestone is the fact, as mentioned by Prof. Boyd Dawkins, that elaterite has been found at Windy Knoll, Castleton, which is right on the other side of Derbyshire. I believe there is one other small " show " of solid bitumen rather nearer the area that is being explored; but neither of these facts indicates the existence of a big field of oil. Apparently the promoters of the scheme have reversed the usual order of things: having found a dome or anticline, they have taken that as sufficient evidence to work upon.

Another point to be considered is that by far the greater number of productive oilfields of the world are of Tertiary age. In America, however, the Pennsylvanian fields are in Palæozoic rocks, and that may have influenced the American advisers in their selection of the area now being tested.

Mr. J. E. Wynfield Rhodes (Manchester): Is there any evidence as to the nature of the Millstone Grit rocks in the centre of the anticline? I understand the collieries have penetrated as far as the Millstone Grit, but have any of them actually got into it accidentally?

Mr. T. Sington: They are about 1,500 feet down from the surface of the land, but I do not know whether they have penetrated into the Millstone Grit at the present time. I do not know the nature of the Millstone Grit over the centre of the anticline; it probably does not differ from the grit exposed along the Pennine Chain.

Mr. Rhodes: There is no evidence that oil ever existed in the Millstone Grit. Is anything known of the nature of the strata at the top of the Grit? Unless there are indications of an impervious band at the top of the Millstone Grit, it seems to me that even if oil had ever existed it would have escaped long ago.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD AT THE HERIOT-WATT COLLEGE, EDINBURGH, FEBRUARY 8TH, 1919.

MR. JAMES NISBET, VICE-PRESIDENT, IN THE CHAIR.

DISCUSSION OF MR. JOHN A. YEADON'S PAPER ON "THE ECONOMY OF BRIQUETTING SMALL COAL."*

The CHAIRMAN (Mr. James Nisbet): The author charges us with wastefulness as a nation of our coal resources. It does not appear, however, that he refers particularly to Scotland. I do not think that, at the present time, there is much mined coal being left in the pits in Scotland. The paper, however, is of interest, as the author brings to our notice the possibility of profitably making briquettes from inferior coal which would otherwise be unsaleable.

The discussion of the paper was closed.

DISCUSSION OF PROF. F. W. HARDWICK'S PAPER ON "THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION."†

Mr. GEORGE HUNTER (Wigan) wrote: The fact that so many papers on mining education have been recently contributed to the *Transactions* seems to indicate that the mining industry is not by any means satisfied with the present conditions of affairs.

I quite agree with Prof. Hardwick "that the time has come when we must take stock of what has been, and is being, done in educational matters relating to coal-mining." We must also look into the future and consider what can be done to improve the present state of things, so as to make sure that we will not be left behind in the future development of the world. It seems to me that much depends on how the problem is dealt with during the period of reconstruction.

The first step would appear to be to draw up a report on the facilities at present existing for such education. The investigation should be thorough, and should cover all the coalfields in this country, on the Continent, and in America. The report should cover at least the following:—

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., pages 31 and 91.

† *Ibid.*, page 94.

(1) The organization and co-ordination of all classes and courses—including continuation schools—junior technical, senior technical, advanced technical, part-time day and evening as well as full-time day courses in Universities and higher Technical Colleges.

(2) In what respects, if any, the industry should co-operate with the Universities, Technical Colleges, schools, and education authorities generally, in regard to schemes, syllabuses, apprenticeships, and finance.

(3) Fees, scholarships, and travelling expenses.

(4) The supply available and the training of teachers.

(5) Provision for research.

The investigations, so far as Scotland is concerned, need not take long to accomplish. The Board of Education and the Scottish Education Department should be able to give valuable assistance in that respect; while a commission, which has been making similar investigations in America, has just returned and will, I presume, issue a report in due course.

After the Institute's report is issued, it could be discussed by representatives from, say, the industry, the Universities, other central institutions, county councils, local education authorities, and school boards in the respective areas, when properly-graduated and co-ordinated schemes suited to the local conditions could be satisfactorily arranged and carried out.

Dr. **Henry Briggs** (Edinburgh): Although systems of training are discussed in a general way in this and previous papers read during the last two or three years, no definite scheme has been put forward in detail in which to try to give effect to the views of the majority of the authors and of those joining the discussion.

I venture to read a draft scheme of co-operative apprenticeship which it is proposed (after adjustment) to bring into operation between a certain colliery company in the East of Scotland and the Heriot-Watt College. It will be observed that it is based on that introduced by the Lochgelly Iron & Coal Company, on which I made some remarks on a previous occasion.*

Proposed Scheme of Co-operative Mining Apprenticeship.

(1) The apprentice shall, on commencing, not be under 17 years of age, and he should hold the Lower Leaving Certificate or its equivalent.

(2) The first year of apprenticeship shall be a probationary period, and the Company shall not be responsible for continuing the apprenticeship until it is assured by the boy's conduct and progress during the first year that the continuance is to the interest of both parties.

(3) The probationary year shall be spent in practical underground

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* *Trans. Inst. M. E.*, 1917-1918, vol. liv., page 153.

mining (apart from mine surveying), and mainly in working with the men at the face and at such operations as brushing and repair-work.

The apprentice shall, during the first year, keep a note-book describing day by day the operations in which he has assisted, and entering therein dimensioned sketches of the tools and appliances used. At the College First Year Course (second year of apprenticeship) a proportion of marks, not exceeding 25 per cent. of those granted for the subject of mining, shall be awarded on this note-book.

(4) During the probationary year the apprentice shall attend evening classes at the College or elsewhere, and his practical work shall be arranged to facilitate such attendance. The object of the classes shall be to prepare for the College entrance examination or (in certain cases) for the University preliminary examination. No classes should be joined without taking the advice of the Professor of Mining. In the case of those eventually intending to practice in metalliferous mining, Spanish should be the language studied.

(5) The second, third, and fourth years of apprenticeship shall be spent in studying at the College for the Diploma in Mining, or (in certain cases) for the Degree, providing that three months of each of these years be occupied in practical work at mines, which may be those of the Company or others, as may be arranged.

(6) The apprentice shall prepare daily records, with the necessary drawings, of the practical work undertaken during the second, third, and fourth years. A proportion of marks, not exceeding 10 per cent. of those granted for the subject of mining, shall, each year, be awarded on the note-books and drawings so prepared.

(7) The Company shall pay the College fees of the apprentice so long as the half-yearly reports of progress, submitted by the College authorities to the Company, show him to be making reasonable progress and to be attending regularly.

(8) The fifth and sixth years of apprenticeship shall be spent at the Company's collieries in undertaking such practical work as the Company's Agents and Managers may direct, providing that the work be of the nature required for the Manager's Certificate and not more than fifteen months be spent in mine-surveying.

(9) During the said last two years of the apprenticeship such evening classes shall be attended as shall, in the opinion of the Professor of Mining, be of assistance for the Colliery Manager's Certificate Examination.

(10) At the conclusion of his time, the apprentice shall sit for the First Class Colliery Manager's Certificate.

(11) Assuming the apprentice to have been successful in gaining the College Diploma, the College authorities shall issue to him the official Mine Surveyor's Certificate as soon as he can show that he has had two years' experience in mine-surveying.

If it were generally accepted, the principle that the company pay the College fees of the satisfactory apprentice relieves a lot of difficulties. The fact that the company may withold fees if the young man does not exert himself at College, gives it the necessary hold and maintains a salutary degree of discipline. The selection of those who are to go to College lies with the company, which is more likely to be able to decide general suitability than the "blind" educational test of the usual scholarship system. Further, the company will not send in more than it can itself absorb, and the difficulty of connecting the College years with practical life will disappear. As Prof. Louis said in the discussion of this paper elsewhere*—and his remarks I endorse from beginning to end—the main difficulty in connexion with College training as we now know it is that of getting the men properly placed at mines when that training is complete. I ventured to comment on this matter in discussing Mr. Kerr's paper.† Though the Institution of Mining and Metallurgy has a well-considered scheme of post-graduate mining scholarship, this aspect of the subject—and it is of fundamental importance—has received no attention at all at the hands of those writing from the coal-mining standpoint.

Another advantage of the scheme just outlined is that it would enable the company, without change of method, to "adopt" into the rank of apprentice any lad in the personnel of the colliery who, by his record at evening classes and in other ways, shows exceptional promise.

I feel that the subject of mining education having been ventilated very thoroughly in a number of able papers during the last few years, the time has come for action. There should be a practical outcome to all this discussion. The Institute should, I think, formulate definite proposals and endeavour to make its views felt in educational and mining circles. I therefore suggest that the Institute now select four or five members to form an educational committee, and ask them to formulate such proposals and report to a future meeting.

Mr. G. L. **Kerr** (Glasgow): With regard to the question of apprenticeship, I think Prof. Hardwick and others who have discussed this and previous papers on the subject forget that there is an apprenticeship in collieries. The position is that no man or boy can become a miner until he has had at least two years' practical work under a miner (Coal Mines Act, 1911, Section 73). The same sort of provision applies to the individual who wishes to become a colliery manager—he must have had five years' practical experience in mining before he can sit for the colliery managers' certificate examination (Coal Mines Act, 1911, Section 9—2*b*). The difficulty in regard to both apprenticeships is that it seems to be nobody's business to direct how these provisions may be best carried out. At present a young man qualifying for a colliery managership is allowed to go into the pits and to serve his time in any way he likes. Further, the same lack of direction and supervision applies to a lad going to the coal-face. I think that throughout the whole of this paper, and throughout a great deal of the discussion, there has been too much of a distinction drawn between the colliery manager and the mining engineer—that is to say, that courses are drawn up for mining engineers or for men who intend to fill the higher positions in mining without any reference whatever to the practical colliery manager. That, I consider, is a point that ought to be kept in view. For instance, in the course of the discussion, Mr. Dron argued that there should be a higher certificate for a colliery agent. I think that would be a mistake, because it is at least my impression that you do not find a successful colliery agent who has not, in the first instance, been a successful colliery manager. In the paper I read before the Institute on " The Higher Training of Colliery Managers " I suggested a scheme which I thought to be the best and most efficient method of securing the higher training that appeared to be necessary and desirable. I may be excused for repeating here what I then said regarding the method of assisting young men to receive the higher training:—

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 121.

† "The Higher Training of Colliery Managers," by G. L. Kerr, *Trans. Inst. M. E.*, 1916-1917, vol. liii., page 182.

> "The best and most efficient method of obtaining this higher training will be by the institution of a number of scholarships or bursaries in the various mining counties of a value of not less than about £50 per annum, to be tenable for a fixed period—say a minimum of 3 years. A scholarship of this value would enable a young man to give up his daily work in the mines for six months each year, and to take a full mining-engineering course, with the necessary science classes. The other six months of the year would be devoted to regular practical work in the mines. By this method the student would not be taken away from the most important part of his training. . . . It is not the sons of the well-to-do parents only that the writer desires should receive this advantage, but the sons of every parent, no matter how poor, if they have the ability and mental equipment to fit them for such a training. For after all it is from the great class of young lads who work daily in the mines (the sons of working miners and colliery officials) from whom we have to look for a continuous supply of managers for our mines. No one should be debarred for want of the necessary means from obtaining the best training possible to enable him to become an efficient manager."*

It is of interest to note on this point the conclusions of the Committee that was appointed by the Government on Coal Conservation, as follows:—

> "*Mining Education.*—At present the Mines Department of the Home Office confines itself to supervising the examination of candidates for mining certificates, but otherwise does not attempt to prescribe the curriculum of the education of such persons. Having regard to the increasing complexity of mining operations, and the increasing need for scientific knowledge both for the sake of safety and for other reasons, it seems desirable that there should be co-operation between the Ministry of Mines and Minerals and the Board of Education with a view to making provision in the schools for some elementary training of a scientific nature which would assist lads in their preparation for mining work and in connection with their future occupation in the mines.
>
> "Moreover, it is recommended that the State should establish some system in the mining industry of scholarships and bursaries, whereby it may be possible for any lad employed in a mine, whether coal or metalliferous, showing ability, to have the opportunity of a first-class mining education fitting him to occupy any position in the industry.

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* *Trans. Inst. M.E.*, 1916-1917, vol. liii., pages 184-185.

"Full use should be made of any Universities, Colleges, and Technical Schools which may be prepared to adapt their curricula to meet the needs of mining education."*

"*Improved Qualifications of Officials.*—Improvements in the various directions previously indicated will come about gradually. They will be hastened by the raising of the qualifications of managers, underground deputies and oversmen, and efforts should be made to raise the standard of qualification among those and other underground officials and workmen as far as possible. Existing educational facilities are sufficient to enable the boy of average intelligence to rise and to fill with credit the position of a responsible underground official, but there should be put at the disposal of the younger workmen the fullest facilities for obtaining mining and technical education. Mining scholarships should be available to men who have shown special aptitude and ability. Candidates for examination either for first-class or second-class mining certificates, who have obtained a high percentage of marks might be encouraged by those scholarships to devote some additional time to special study and investigation before assuming the responsibility of management. The result of this policy over a number of years would be seen in greatly increased interest and efficiency. The personal interest of the employer in this aspect of the problem needs to be awakened so that encouragement and guidance may be given to employees who have proved themselves worthy of support. The effect of such personal interest would be to create an atmosphere of practical sympathy and support between the employer and the management, and between the employer and the workman, which would be certain to lead to improved relations at the collieries and consequently to better all-round results."†

This Report is signed by, amongst others, Mr. Robert Smillie, of the British Miners' Federation—so that you have the considered point of view of the workmen—and by Sir Adam Nimmo, Col. W. C. Blackett, Mr. John Gemmell, Mr. W. Forster Brown, Sir R. A. S. Redmayne, Mr. C. E. Rhodes, etc., representing the views of the coal-owners, mining engineers, and the Home Office. That, then, is the Committee's final report and final recommendation on this question, and it should be carefully read and acted upon. It seems to me that there has been far too much talk on the whole question, and it is now really time that something practicable was done. First of all, I think that the coal-mining industries must get into very much closer touch with the Universities and Technical Colleges and learn what they are capable of doing there. The Technical Colleges, indeed, should be far more closely allied to the mining industry, and be financially supported to do their important work. It is pitiful to see trained professional men at the Technical Colleges teaching six or seven individuals at a day class when they could quite as easily supervise the work of fifty students.

MR. J. BALFOUR SNEDDON (Mid-Calder): I would like to correct Mr. Kerr on one point. The classes in elementary schools are being reduced to thirty, and fifty would surely be rather a big handling for a mining class.

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* *Coal Conservation Committee; Interim Report of the Mining Sub-Committee*, 1918 [Cd. 9084], pages 43-44.

† *Ibid.*, *Final Report of the Mining Sub-Committee*, page 62.

Mr. KERR: I refer to the professor and his assistants and not to a single teacher taking fifty students.

The further discussion of the paper was adjourned.

DISCUSSION OF MR. DAVID PENMAN'S "DIGEST OF THE FIRST REPORT OF THE MINE RESCUE-APPARATUS RESEARCH COMMITTEE."*

Lieut.-Colonel **D. DALE LOGAN**, D.S.O., M.D., D.P.H., R.A.M.C. (Newmains) wrote: It may be of interest to consider the results of the investigations of the Mine Rescue-apparatus Committee in the light of our experience on the Western Front.

At present, the onus of choice of apparatus is placed on the coal-masters. This is thoroughly unsound, although one good result of it has been that several of the coal-masters' associations, and Sir William Garforth, started independent investigations into the merits of the various types of apparatus, and were fortunate to obtain the services of Dr. J. S. Haldane, Sir John Cadman, and others. Attention was called to a number of defects in apparatus, the physiological requirements of rescue-apparatus were pointed out, and the whole question treated in a thoroughly scientific manner. Dr. Haldane insisted that an apparatus to be of any value in rescue-work must suit itself to the man and his work, not the man and his work to the apparatus. The result of the outspoken criticism in these reports was an immediate improvement in apparatus and the disappearance of the most glaring defects.

Previous to this, the work of improving apparatus had been left to the good intention of makers, who, however keen they might be to improve their apparatus, were naturally prejudiced and the last to discover faults. The people who discover faults in an apparatus are not those who make it, but those who wear it. I consider that the extravagant claims regarding the efficiency of apparatus put forward by some of the makers—claims which were not substantiated by results achieved—constituted a real live danger. For example, the makers, almost without exception, estimated the life of the apparatus by the quantity of oxygen carried—the capacity of the absorbent to deal with carbon dioxide and the comfort of the wearer being entirely ignored.

These serious handicaps to efficient rescue-work, combined with the want of proper guidance in training, have contributed to the regrettable number of lives lost both in training and during actual rescue-work in England. Indeed, when one considers the disappointing results in the past, when one compares the losses among men wearing apparatus and the number of lives saved, one is almost inclined to question the advisability of countenancing any further development of organization, and the great expenditure of money which would be entailed. Notwithstanding the past record of rescue-work in England, the work with apparatus in military mining in France shows what can be done with a sound organization, and, with the great improvement of apparatus and the more efficient organization which is bound to follow the splendid work of the Research Committee, valuable rescue- and recovery-work at colliery explosions and fires will soon result.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 236.

With reference to the report of the Research Committee, a number of the points which they have insisted on—for example, the prevention of structural defects of apparatus by State supervision before it leaves the makers, the more thorough training of men under conditions approximating as nearly as possible those encountered in actual rescue operations, certain defects of apparatus which require modification and improvement, the importance of proper selection of mine-rescue men, etc.—have already been discussed in considerable detail elsewhere, and strong support for their conclusions have been furnished from our wide experience in the trenches.

In reading reports of rescue-work after colliery explosions and fires in which apparatus was used, one is struck by the want of proper organization. Accidents due to defects of apparatus and to the want of careful examination of apparatus before beginning work have been much too common, and might have been avoided if there had been efficient control and supervision of the men. Mine rescue-work is frequently undertaken in the most light-hearted way possible, in a number of cases no proper preparation being made and no schemes of work drawn up. It cannot be too strongly emphasized that efficiency of apparatus will not make up for want of organization, and that rescue-apparatus which is not properly looked after and periodically inspected is little short of a death-trap.

I am quite convinced that much of our success in rescue-work and actual mining operations, carried out by men wearing the apparatus under the most trying conditions, was due to the fact that there was the strictest discipline. The want of discipline and the non-observance or disobedience of orders may involve a whole rescue-party in disaster and seriously retard rescue-work.

Regulations have already been issued for the provision of rescue-apparatus and other rescue-appliances, and for the maintenance of certain rescue personnel in each colliery area; official inspection, supervision, and direction of both design and training should follow as a natural corollary. An early result of the Committee's Report should be a reduction of the number of types of rescue-apparatus recognized by the State; multiplicity of type is generally more or less a confession of failure, and one or two of the apparatus, in their present form, are an absolute danger to the wearer.

The Committee advised—

> "That an Inspector should be appointed under the Mines Department of the Home Office, whose function it would be to advise the Chief Inspector of Mines as to the safety of these apparatus, to see that the regulations regarding rescue operations were properly carried out, and that apparatus at Central Stations and Sub-Stations and mines were maintained in condition fit for immediate use."

Undoubtedly the appointment of an Inspector of mine-rescue organization and training, corresponding to the Adviser at G.H.Q., France, and with similar duties, general supervision of training, rescue-work, apparatus, etc., is called for. But in view of the special character of mine-rescue organization and the necessity of close supervision of training and rescue-stations, it is quite impossible for an Inspector to carry out all the work, and, therefore, it would be necessary to appoint Sub-Inspectors of rescue-work in each district, whose duties would correspond with those of our mine-rescue school officers. In my opinion this is the only way to set up a really efficient organization. The Sub-Inspectors would be directly responsible for the general control, inspection, and equipment of all mine-rescue stations in their districts, the supervision of all apparatus and material, the supervision and inspection of training, and they would forward reports and recommendations direct to the Chief Inspector. They would also undertake the general direction of rescue operations if these should arise in their area. This would necessitate a knowledge of various collieries.

As we have seen, guarding against structural defects of apparatus is absolutely essential, but this does not do away with the necessity of the most careful storing and supervision of all apparatus after issue, as the vast majority of accidents due to faults in apparatus are caused by improper storing and want of constant supervision. The constant supervision of apparatus and rescue stores would, therefore, be one of the most important duties of the Sub-Inspectors.

If it is intended to take further action in the control of apparatus in mines, it is useless merely to approve a type unless provision is made for constant improvement, based upon the experience of the various rescue training-stations. It would be the duty of the Sub-Inspectors to encourage such work at the rescue-stations, collect all information, and forward it to the mining department, where it would be investigated by the Chief Inspector.

Another of the chief duties of the Sub-Inspectors would be to make it a personal matter to attend team practices and see that the useless practice of walking about in a leisurely way for an hour or so while wearing apparatus was done away with, and its place taken by such work as really represents the conditions in a mine explosion.

The valuable work done by Sir John Cadman at Birmingham University, Dr. Haldane at Oxford, and more recently by Dr. Briggs at the Heriot-Watt College, Edinburgh, points to the necessity of providing facilities for the chemical side of the research, either by continuing the present arrangement with the Department of Scientific and Industrial Research, or, if there are any difficulties in the way, by providing a well-equipped laboratory and workshop and appointing as assistant a thoroughly-trained mechanical engineer capable of appreciating the advantages and defects of the details and design of apparatus.

If a Ministry of Public Health is formed, it is very desirable that there should be a properly-qualified medical inspector in connexion with mining—one who has an intimate knowledge of the diseases peculiar to miners. This appointment should be combined with that of the Inspector of Rescue Organization. It seems undesirable to separate them: both have to do with the elimination of dangers to health and life. An arrangement similar to this worked well in France, where the Adviser in Mine-rescue Organization also supervized the Special Medical Services of the Tunnelling Companies.

Mine-rescue work in France presents many points of difference to the conditions prevailing in mine-rescue work at home. In France, the call for the use of apparatus was so frequent that entering and exploring galleries after a mine had been blown either by the enemy or by us became a matter of routine. When it is stated that in 1916 nearly 1,500 mines were blown along our front, the magnitude of the work may be appreciated. It was nothing unusual for a tunnelling officer (all of whom were trained in the use of apparatus) to turn out at a moment's notice with a team, proceed to investigate any special part, and afterwards carry on with his ordinary trench duties. When it is realized that a tunnelling officer was usually in the trenches for from two or three days at a time, during which period there was little time for rest or sleep, the exacting nature of his work—general superintendence of mining work, listening, and mine-rescue—becomes more evident.

The men usually worked in 12-hour shifts, but at other times lived in the line and worked three 8-hour shifts, with intervals, afterwards returning to billets for two days. Although military mine systems were much less extensive than small collieries, and the length of roads to be traversed by the men much shorter, it must be remembered that rescue-work had frequently to be carried on under shell fire, and surrounded by all the dangers, discomforts, and difficulties of trench warfare. The strain on all ranks during the intensive mining activity preceding the Somme, Vimy, and Messines attacks can well be understood, and the fact that during the months preceding these attacks apparatus was used many hundreds of times with few accidents indicates the degree of skill attained.

Never before has training and rescue-work been carried out on such an extensive scale. When it is grasped that in one army school alone for many months no fewer than 120 100-cubic foot cylinders of oxygen were used monthly, and in the same school and in the Tunnelling Companies administered by it no fewer than 450 Proto and 250 Novita sets were in constant use; that at least 1,500 Proto and Salvus sets were distributed along the whole front, with over 500 more for training and reserve at mine-rescue schools, it will be realized that civilian experience is on a pigmy scale compared with that obtained under the most adverse conditions of trench warfare.

The scale on which apparatus was used produced an organization efficient both in equipment and personnel. It is doubtful whether, under the conditions of civil life, it is possible to get such results, which were due not only to the personal pluck, perseverance, and endurance of picked men, but also to the constant training and practice under actual working conditions and strict military discipline.

The result of the mine-rescue organization—one quite new to warfare—has been that many valuable lives have been saved and important assistance in other ways given to mine warfare. Many defects of apparatus were discovered and corrected during the intensive training in the schools and actual work in the front line, and valuable modifications were suggested and carried into effect, so that the mining world has profited by the work done on the Western Front.

Dr. HENRY BRIGGS (Edinburgh): As a member of the Research Committee responsible for the First Report, I do not think that I ought to take part in a discussion of its details. I had very much rather hear other members express their views, since there are many in this Institute who could assist the Committee by helpful criticism. I, however, welcome the opportunity of speaking on the more general question of the bearing of a research like this. Mining history shows that progress in regard to measures of safety has often been delayed until fatal accidents or large-scale disasters have stimulated enquiry or provoked legislation. Even when an advance has been made along a given line, we have been much too ready to rest on our laurels and let things slide until our elbow, so to speak, is given another violent jolt. To wait until men are killed before moving ought surely, as a method of progress, to be scrapped. Enquiry and research, directed to the more economical working of mines and to the protection of those engaged, should be a continuous process, and not taken up by fits and starts. The Department of Scientific and Industrial Research, which is in efficient hands, is seeking to stimulate and support such researches; to relieve them of the risk of financial starvation; and to publish results in the fullest and most accessible way. We may hope that in mining and kindred branches of technology the future will see a great widening of the field of enquiry under the survey of the Department and the Associations which are to be set up by it.

The research on rescue-apparatus, which is the first big subsidized research in mining to bear fruit, is unfortunate in one respect. It would have been better if the pioneer enquiry of its kind had been able to steer clear of legislative matters. One of my main purposes in speaking to-day is to try to remove the impression, if it exists, that mining research may lead to a still further tightening of what is regarded by some as the Home Office stranglehold. Most of the problems to be attacked in large-scale research are free from the legislative question. Even in this instance the result will be more the alteration and repair of existing rules rather than the building of new ones.

Most of the members will remember the circumstances which led in 1910 to the passing of the Rescue and Aid Bill through Parliament, and how, owing to some magic in the very words "Rescue and Aid," an Act compelling the use of rescue-apparatus became law, before it had been properly considered whether such apparatus were themselves safe and efficient. Now that Mr. Robert McLaren, our President-elect, sits in Parliament, we may hope that he will exercise a steadying influence in that exuberant body when next it attempts mining legislation. The mine-owners at that time had no option but to buy the apparatus then sold; and often which of the apparatus they purchased depended more on the astuteness of a commercial traveller than on any advantages the apparatus itself might possess. In these circumstances, it can hardly be wondered that a number of lives were lost while using the apparatus, nor that these appliances became viewed with distrust. In the attacks which followed on rescue-apparatus in general, Colonel W. C. Blackett stood out as Peter amongst the Apostles, and the gospel of its uselessness found ready acceptance in Scotland, where it eventually led to the famous smoke-helmet controversy between the Scottish coal-masters and the Home Office.

Even if the present Committee succeeds, as it hopes, in devising or assisting to devise safe and serviceable forms of breathing-apparatus, it will take many years before the spirit of antagonism is dispelled in certain quarters and before it is admitted that such appliances have their decided uses in their own particular sphere.

It is obvious from the Report that many changes will probably be made in the regulations respecting rescue-work. How many of our recommendations will be acted on by the Home Office, it is not my business to indicate; but one, namely, the inclusion of the oil-shale mines under the Order, is of special interest to Scotland, and stands out as one of a number of suggestions upon which the Committee would like to hear the opinion of the members.

Mr. RICHARD KIRKBY (East Wemyss): I notice that on page 18 of the official Report there is a recommendation to abolish half-masks. I hope that particular recommendation will be very fully considered before it is finally adopted. It seems to me that it is a great pity that we cannot get a face-mask—a sort of half-mask—which would be both efficient and safe. I have no particular information at hand on the point, but I think that more accidents happen with the mouthpiece than with the half-mask. I think Mr. Stevenson, of the Cowdenbeath Rescue-station, has some ideas on that point, and that he has introduced a mask which possesses the merits of being properly made, safe, and simple. I have seen at the Wemyss sub-station a mask which I think is even better than that used by Mr. Stevenson at Cowdenbeath. It is certainly very much smaller—just passing round the wearer's nose and mouth. It should be kept in mind that there is one very important advantage that the half-mask has over the mouthpiece, namely, a telephone can be attached to it. Mr. Stevenson can possibly furnish us with additional details in regard to that matter. I may say that he and the Superintendent at the Wemyss sub-station between them arranged a telephone connexion. By this connexion the wearer can be told exactly what is going on around him, and certainly it seems to me a far better arrangement than that of signalling by means of bells. Signal "one" might in reality be caused by a fall; and signal "two" might be due to precisely the same cause.

Mr. DAVID STEVENSON (Cowdenbeath): I quite corroborate all that Mr. Kirkby has said on this point, and it seems to me that the whole thing resolves into merely the exercise of a little care in putting on the half-mask. If you take that care, then you are certainly afforded a comfort that the mouthpiece does not give. When a man is able to speak to his neighbour in-bye, exploring in a poisonous atmosphere, it naturally brings a great deal of comfort. I am well aware that some people appear to be rather prejudiced against wearing the half-mask in rescue operations, but I am like Mr. Kirkby in thinking that a sufficient amount of consideration has not been given to this particular point.

Another question that I think ought to be dealt with has reference to the leakage test. I may say that in the case of the apparatus used at the Cowdenbeath Rescue-station I fail to see how we can get a satisfactory leakage test by the means described in the First Report. A little further on the Report states that "No apparatus should ever be used where such has a receptacle, etc." On this point I am clearly of the opinion that there could be a far better test of the apparatus than that described in the Report.

Mr. George Welch (Coatbridge): I do not approve of the half-mask at all. There is one part of the Digest to the First Report which deals with the supply of oxygen for the cylinders, and where it is suggested that provision should be made for a 2-litre supply. I do not entirely agree with Mr. Penman on that point. Another point is in regard to the testing of oxygen. In our station at Coatbridge we have the maker's guarantee, and if the oxygen is certified as being up to the standard required by the Act, it is passed out to the instructor and the men. In such a case as that it seems to me that where there is a maker's guarantee the people supplying the oxygen should be held responsible for any default. On page 44 of the Report is a proposal to institute competitions between brigades. Personally, I think that it is a most unwise thing. A large number of colliery brigades are trained in the mines-rescue station at Coatbridge, and it seems to me that if you introduce a spirit of competition among these men you will be encouraging them to over-exert themselves with the apparatus. The whole thing may finally result in bodily injury to members of the team.

Mr. J. Balfour Sneddon (Mid-Calder): I observe from the Report that it is recommended to include within the provisions of the Rescue and Aid Order some of the mines that have hitherto been exempted. The Scottish oil-shale mines are part of those which in the meantime are excluded from the operations of this scheme. It is said in the First Report that "very few mines can be considered free from all risk of fire, etc." I am in the unfortunate position that I have probably to look "a gift horse in the mouth." In regard to the two incidents referred to in the Report, we certainly were quite glad that the rescue-apparatus was available as a stand-by and for possible contingencies. We were really indebted to the rescue-brigades and quite glad to have them there. I would be inclined to argue the point if it was claimed that the practical effect these rescue-brigades produced was such as to justify the finding that the oil-shale mines should be included within the scope of the Rescue and Aid Order. I do not wish to depreciate the efforts of the brigade teams in any way, but I am bound to say that we were more indebted to the men comprising the rescue-brigades than to the equipment they used. These men were accustomed to working under adverse and difficult conditions, and they gave us considerable assistance, while their suggestions were at all times most valuable. From that point of view we were certainly indebted to the rescue-teams. The actual outcome, however, of the presence of the brigades so far as saving and preventing the destruction of property do not amount to what could be described as a distinctive success. I would suggest to Dr. Briggs that as a member of the Research Committee he might leave out the Scottish oil-shale mines until the apparatus is of more practical use.

Mr. James Cooper (Edinburgh): I agree with Messrs. Kirkby and Stevenson that there should be some further research in connexion with the half-mask before it is finally laid aside. Like Mr. Stevenson, I am of opinion that in cases of emergency where men are in danger, or where a rescuer is upset to some extent, the voices of fellow members of the team, heard distinctly by wearing the half-mask, would have a steadying influence. Indeed, it is possible to conceive circumstances where the voice of a fellow-member of a team would prevent another from getting into a panic. We know quite well what the effect of a panic would be in a dangerous atmosphere: the men would lose control of themselves, and they would quite naturally try to revert to normal breathing again. The result of that would possibly be disastrous. With the half-mask one member of a team can speak quite clearly to a fellow member, so that there is a direct steadying influence which might be helpful just at the psychological moment.

On page 35 of the Report references are made to medical examinations and physical fitness. On that point I have formed the quite definite opinion that members of rescue-teams should be medically examined at least once a year, in order to test whether they are still fit to carry on the work and to wear the apparatus. On page 36 a recommendation is made that there should be quarterly practices. Personally I think that quarterly practices are far too few for efficient training. From the experience acquired during the past 2½ years, I am quite convinced that one practice per month ought to be the minimum number. Like Mr. Welsh, I do not believe at all in this competition idea. It is very easy with the existing breathing-apparatus for a man to over-exert himself, as he would be likely to do if spurred on by the rivalry engendered in a competition. Until we get a more satisfactory machine than at present, it would be decidedly unsafe—unless, of course, the work was so carefully arranged that men could not over-exert themselves very much.

Mr. DAVID PENMAN (Edinburgh): In view of the discussion that has taken place, I would like to point out that in the First Report of the Research Committee censure is directed only against existing types of helmets and face-masks. In considering the merits and demerits of the two forms of face connexion, it must be clearly kept in mind that the first essential feature is safety; comfort, convenience, and other factors must give place to safety. If you cannot get a half-mask that is absolutely safe under all conditions, then I think you ought not to use it. The weak feature of the mouthpiece connexion is the nose-clip, because it is difficult to ensure that it will not slip off or be knocked off, but otherwise the mouthpiece makes practically a perfect face-joint. In the work of the research, attention has been directed to the production of a type of nose-clip which is not easily knocked off, and it is believed that this problem has been solved satisfactorily. At the same time, I should like to assure the members that the Research Committee are not unmindful of the advantages attached to the half-mask. An endeavour is being made to secure a form of half-mask that will be safe. If such can be found, then I do not think that the principle of the half-mask will be altogether discarded.

The further discussion of the paper was adjourned.

DISCUSSION OF MR. P. A. MOSSAY'S PAPER ON "COOLING OF ELECTRIC MOTORS, WITH SPECIAL REFERENCE TO TOTALLY-ENCLOSED MACHINES."*

Mr. JOHN BLACK (East Wemyss) wrote: Most engineers will agree, I think, with the author regarding the heat problems in connexion with electric motors and generators. There are, of course, difficulties to be met with when installing motors in pits underground, particularly when the mines are fiery, and totally-enclosed motors are therefore necessary. My experience with such motors is limited to direct-current coal-cutters, and with these a considerable amount of heat is generated at the commutator. This can be decreased in many cases by selecting a suitable quality of brush and in decreasing the brush spring-pressure. The correct quality of brush makes all the difference, and it pays to go thoroughly into this matter.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 103.

Another fruitful source of heat trouble is to be found in the heavily-varnished armatures, rotors, stators, and field-coils, even when these are new from the makers, but more particularly in connexion with repaired work. The idea appears to be that the more varnish is applied the more satisfactory will be the job; but while this is true as regards di-electric strength, it is unfortunate that varnish is a bad conductor of heat, and therefore prevents the transfer of heat from the copper to the outer air or other cooling medium, resulting in an excessive rise of temperature with frequently disastrous consequences. Good practice would therefore point to a thin coat of very good varnish, and the same remark could be applied in a general sense also to insulating material, such as mica, empire cloth, prepared tapes, etc., due regard being given to the important matter of heat-dissipation.

Having got the heat to the outside of the machine (and this applies to all motors or generators), another problem presents itself for satisfactory solution, namely, the removal of this heat from the motor-room. It is preferable, although not always possible in a pit, to lead a supply of clean cool air to the various motor-rooms, and this can be done at little expense by installing a fan in such a manner that it draws air through a fine water-spray filter, discharging the same into the motor-room at a water-gauge of, say, half an inch. With such an installation the motor heat is continuously carried off and little or no dust is deposited in the motor. Modern water-filters are so efficient that free moisture in the air-discharge is practically unknown.

In many instances motors of the pipe-ventilated and totally-enclosed types need not be installed, as the protected type would suit the foregoing conditions, and, moreover, the simpler and more accessible the motor is, the better it will be from all points of view, which is indeed true as regards all machinery.

Would Mr. Mossay state in his reply how he proposes to build a totally-enclosed motor to compete in price with an open-type motor? Does he seriously state that the price of each is the same? It would also be of interest to see a curve, similar to that shown on Fig. 13 (page 114), of temperatures taken from a 10-horsepower motor of the ordinary totally-enclosed type.

MR. ROBERT W. PETERS (Lochgelly) wrote: This new method of ventilating totally-enclosed motors, introduced by Mr. Mossay, is certainly a distinct advance on the methods previously employed. The disadvantages of these methods, as applied to coal-mining, are chiefly—

(1) Machines too heavy and out of all proportion to their

horsepower, and consequently very costly and difficult to transport from one place to another underground.

(2) Owing to the cooling systems being directly applied internally, breakdowns are caused by oil-vapour from the bearings being drawn in and deposited on the windings, thereby adversely affecting their insulation. It has also been known that owing to this loss of oil the bearings have run dry and seized.

(3) Where the machines are working in a dry and dusty atmosphere, it will be found that the ventilating ducts become choked, thereby defeating the very object for which the ventilation was primarily intended. In this new design of machine, it is quite obvious that the above disadvantages of the old methods are entirely eliminated.

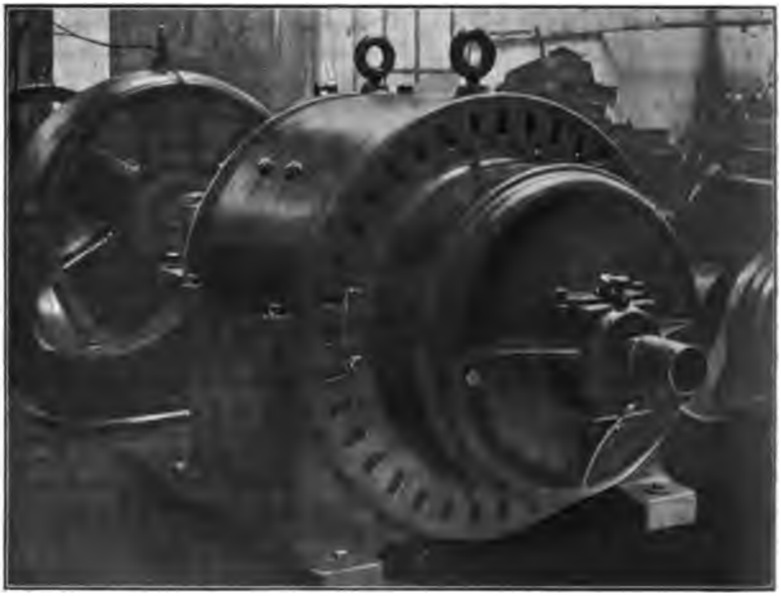
Would Mr. Mossay state what would be the temperature-rise of this new design on a 50-horsepower totally-enclosed alternating-current motor operating on a 500-volt three-phase circuit in an atmosphere at 70° Fahr., or in extreme cases at 80° Fahr., which may arise in deep workings?

Mr. **James B. Laird** (Armadale) wrote: If it is possible to get the results claimed without interfering seriously with the efficiency of the motor, the author has solved a problem that must have entailed a great amount of research and experiment. Coal-cutter manufacturers have done a similar thing with the ventilation of alternating-current motors.

How would the author apply this to a consequent pole direct-current coal-cutter motor, and what would be the actual cost of the motor per horsepower, the efficiency, and the temperature-rise on different sizes? Their actual size compared with a modern type enclosed motor by our best manufacturers would be interesting.

Mr. **P. A. Mossay** (London) wrote: Mr. John Black rightly points out the importance of the nature of the insulation on the operation of totally-enclosed motors. The usual practice in building totally-enclosed motors is to fit covers to an open machine, and to use all its standard electrical parts. I contend that this practice is wrong. The windings of an open machine are generally over-insulated so as to prevent dust and dirt from collecting in the interstices of the winding and core. This cannot happen in a totally-enclosed machine, and it follows that the design and insulation of this class of machine should be laid out on quite special lines. In other words, the design of an Emcol motor should be entirely different from that of an open machine in order to satisfy my claim that the price of such a machine can be brought very near to that of an open machine of the same rating.

I have lately had the opportunity of demonstrating this in a practical manner. A 50-horsepower Westinghouse motor running at 750 revolutions per minute was put at the disposal of my colleague (Mr. H. C. E. Jacoby) and myself for alteration into an Emcol motor. This motor was fitted with a new frame and end shields, entailing an extra cost of about £5 above the standard open-ventilated design. The armature, field, and poles were not in any way altered. The motor was fan-ventilated before its alteration into the Emcol type, so that it formed one of the most difficult cases with which to contend. As an open machine, the maximum temperature on the field was 35° Cent. As an Emcol machine, the same winding gave 47° Cent. rise—that is, only 12° Cent. more, despite the fact that the temperature of the interior air was 26° Cent. above that of the air outside.



50-Horsepower Westinghouse Motor Altered into an Emcol Motor.

The field-winding consisted of divided spools, and was of a design suitable for totally-enclosed motors; hence the reduction of temperature-rise relative to the surrounding air. On the other hand, the armature was of the worst kind for totally-enclosed motors, although eminently suitable for an open-ventilated type, and here the results were not so good, the temperature-rise as an open machine being 28° Cent. and as an enclosed machine 50° Cent.

On the basis of these tests, I have no hesitation in saying that with a re-designed armature the output of this motor, when arranged as an Emcol motor, could be increased to 65 horsepower within the temperature limits of 50° Cent. rise.

The photograph shown in the text illustrates this motor on test. I regret that I am unable to produce a heating curve of a 10-horsepower three-phase totally-enclosed motor of the orthodox type for direct comparison with the curves shown in Fig. 13 (Vol. LVI., page 114). Such a machine could be built and have the same temperature-curve as the one shown in the paper, but its bulk would be far larger and its cost well double that of the Emcol machine; in fact, one of the leading makers in this country lately offered for the 10-horsepower rating a machine weighing 1,000 pounds against 550 pounds for the Emcol motor described.

In reply to Mr. Robert Peters, the temperature-rise of a 50-horsepower three-phase Emcol motor, suitable for deep working where the temperature may be as high as 80° Fahr., could be kept well within the limits specified by the British Standard Rules.

In reply to Mr. James R. Laird, it is possible to obtain these results without interfering with the efficiency. On the contrary, I claim that Emcol motors can be made with a considerably higher efficiency than that of the orthodox enclosed motor by reason of the fact that the bulkier machine entails a larger mean length of turn of the windings, larger bearings, and a larger commutator, and therefore higher total losses. The power taken by the fan can be kept well below ½ per cent. of the output.

I regret that I am not able to answer Mr. Laird fully on the specific question with regard to coal-cutter motors. This is a matter which I propose to investigate very shortly, but I have full confidence that what has been done up to the present can be done under my patents more cheaply, efficiently, and with a lower temperature-rise—that is to say, it will be possible to increase the power and scope of the coal-cutters as at present built.

The further discussion of the paper was adjourned.

AN ELECTRIC HEAD-LAMP.

BY J. COOPER.

Introduction.—The new and safety type of head-lamp to be described has lately been introduced into American mines, where in a short period 100,000 of them are already in use.

As instructor in mine-rescue work at the Edinburgh Station, I have worked for two years with the Oldham, Ceag, Wolf, and Edison-Davis lamps, although most of the work at the station is carried out with a lamp of the Wolf type. As it was noted that the hand-lamp retarded the men from carrying on their work easily and quickly, it was thought that an improvement could be effected in the type of lamp employed. The Edison electric-head lamp for the past six months has been used in the work of the station. It has given great satisfaction, and is eminently suitable for all phases of rescue-work. As only one was used, the leaders of the teams invariably wore it, and all agreed that it was a decided improvement on the ordinary lamp.

When a man is supplied with a light that leaves his hands and attention entirely free throughout the shift, and the light is placed in the best position for carrying on underground work, it follows that the highest efficiency is secured. From the experience gained, it may be claimed that this lamp combines the advantages of the ordinary open head-lamp, as regards position of light, with the security of the safety-lamp. It does not require to be trimmed or supplied with fuel like the former, or to be handled with extreme care like the latter.

With regard to the attention required by an open lamp, observations made in America and data collected there show that from 30 to 55 minutes is taken up by each employee in an 8-hour shift in keeping his open-lamp flame adjusted. In these days, when the shortage of labour is affecting the coal output so materially, any change of equipment that will permit the men to devote from 30 to 55 minutes more per shift to their work should be adopted as quickly as possible. A detailed description of the lamp will now be given.

Battery.—The lamp-battery consists of two Edison nickel-iron-alkaline storage-battery cells, which fit into a light case of rust-proof metal. There is no insulation between the cells and the case, and the contact springs on the cell-poles hold the battery securely when the cover is in place. The cover has a removable hinge that permits of its entire removal when open, and thus facilitates the charging of the battery. The lamp is in contact immediately the cover is in place. The two cells are connected in series and have free terminals carrying the spiral contact springs, which press against nickeled-steel contact-plates in the cover. The contact-plates are insulated from the cover and receive the cable terminals.

Cable Connexion.—A twin conductor rubber-covered cable connects the battery to the cap-lamp. The cable is thoroughly armoured at each end, and thus prevents injury from sharp bending.

Lamp.—This consists of a nickel-plated brass reflector, with a hook to fit into the regulation miner's cap. A tungsten lamp is forced into a spring-socket by means of a clip at its top, in such a way that if the lamp be broken the base is immediately disconnected and the lamp extinguished.

Method of Attachment.—The miner straps on the battery-case by means of his ordinary belt. The battery can be hung at any part of the body, but for men wearing breathing-apparatus the most suitable place is on the right hip.

Weight and Dimensions.—The total weight of battery, case, and lamp is 3½ pounds. The height of the case is 6⅝ inches and the horizontal dimensions are 1¾ by 6 inches. The lamp burns for twelve hours per charge on a 2½-volt average discharge.

Cost.—From detailed reports available over a period of two years, it is found that the average cost of maintenance of electric cap-lamps will not exceed 1¾d. to 2½d. (3½ to 5 cents) per lamp per shift. These figures include the original cost of installation, all repairs, etc., and represent the maximum outlay.

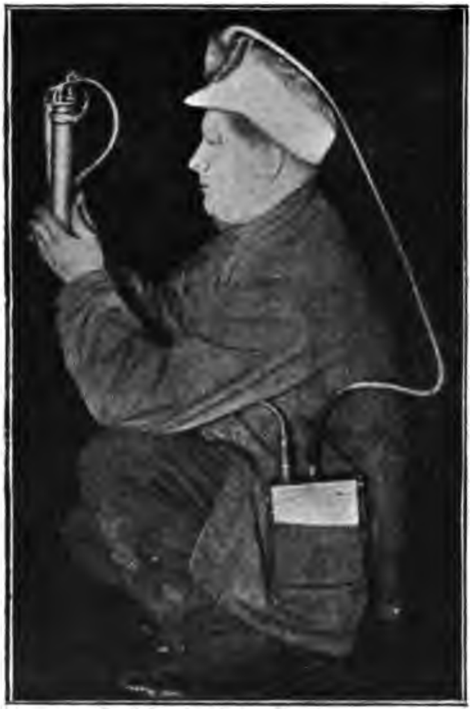
Use of Head-lamp in Rescue-work.—The experience which has been gained by the writer in the ordinary work of a rescue-station has convinced him of the superiority of this lamp over the hand-lamp.

In combating a fire and when exploring a mine after an explosion, the essential equipment carried by a rescue-brigade would be easier dealt with if head-lamps were used. This remark also applies to brigade-training and to actual rescue-work, as the use of the equipment is greatly retarded by having to carry a hand-lamp.

When applying artificial respiration underground, the use of a light placed in a proper position is required in order to note the effects of the treatment. A head-lamp would give the best results.

In operating a service telephone in a mine, and in handling a water-hose when quenching a mine fire, the freedom of both hands is necessary if the movements are to be unrestricted. In such work, an ordinary hand-lamp is an encumbrance, while, on the other hand, a head-lamp is clearly most suitable.

A striking operation of rescue-work, when the light should be on the head and the hands free, is when carrying a man on stretchers. While crawling in low workings or surmounting falls, the usual position of a hand-lamp slung at the end of the stretchers-pole becomes impracticable, and the practice generally followed is for the bearers to place their lamps on the stretchers. This is an awkward arrangement, as the leading bearer then moves along in darkness, while by using a head-lamp a suitable illumination is secured.



ELECTRIC HEAD-LAMP, WITH BATTERY AND CABLE.

The operation of putting up boarding, screen-cloth, and air-tubes requires two men if the ordinary hand-lamp is employed. By the use of a head-lamp all these operations can be carried out by one man. Building permanent stoppings and carrying forward material would be more accurately carried out and better speed attained by the use of the lamp described.

In rescue-work one has to remember that the cylinders of a breathing-apparatus carry only 2 hours' safe supply of oxygen; any fraction of time gained is therefore valuable—in fact, the shorter period of time in which work could be carried out might turn the scale in saving the lives of imprisoned men.

General Application to Mining.—In sinking, either in wet shafts where the open light has to be protected from water, or in any others where the safety-lamp is usually employed; in machine-mining, where space is restricted and coal-cutters, etc., require to be examined and temporary repairs made; and in rope-splicing, when it is absolutely essential that a man's hands should be free, his movements unrestricted, and a good light required, it would be a saving of labour to use the head-lamp. For transport-men, timberers, repairers, and generally for all classes of underground workmen, owing to the facility of action and freedom from attention, the adoption of the head-lamp would certainly tend to increased efficiency, saving of labour, more pleasure at work, and consequent increased output.

Drawbacks.—It cannot be used to detect the presence of firedamp. It may be mentioned, however, that a new indicator has been lately introduced into American mining for the purpose of estimating the percentage of inflammable gas in the atmosphere. A sample of the mine air is sucked into a tube, which forms a combustion-chamber similar to the Haldane type, the current for burning the gas being supplied from the lamp-battery by inserting a suitable plug in the top of it. The inventor claims that this apparatus gives accurate results. Another disadvantage is that the cable attachment from the battery to the lamp has to be led over the head, and, owing to its position, is liable to catch on any projection.

Suggestions to Increase the Candle-power of Electric Lamps.—In certain circumstances, such as the work of rescue-teams in a smoky atmosphere, it would be an advantage to have a stronger illumination than that given by the two-cell type of lamp. As the weight and dimensions of the Edison cell is comparatively small, a four-cell battery could be employed and thus increase the lighting power. Another method whereby it could be strengthened in its intensity is to decrease the life of the lamp-bulb. The ordinary kind used has a life of approximately 250 hours. This need not be so where light is the ruling consideration, as in combating a fire. The writer would suggest, therefore, that a life of 100 hours for a bulb would be quite enconomical, considering the purpose for which it is required. By increasing the voltage above the rated pressure of the bulb, a more intense light would be produced, a 5-per-cent. increase above the normal voltage would increase the candle-power by 30 per cent. The illuminating power being proportional to the fourth power of the voltage. By a combination of the two methods the illuminating power would be still further increased.

In conclusion, it may be stated that the lamp has been submitted to an electrical expert, who reports that it is strongly constructed, not liable to get out of order, and will stand hard usage. As a part of the equipment of a rescue-station, the teams would certainly find it of great assistance in their arduous labour, and feel greater confidence and freedom in actual rescue operations.

All reference to the lighting provisions of the Coal Mines Act have been intentionally omitted from the paper.

The photograph in the text gives a view of the lamp and shows the method of wearing it.

Mr. J. BALFOUR SNEDDON (Mid-Calder): Do the figures given relative to cost extend over any length of time?

Mr. JAMES COOPER (Edinburgh): Over a period of two years. I understand that was the cost in America.

The CHAIRMAN (Mr. James Nisbet): Do these figures apply to a pre-war period, or are they applicable to the present time?

Mr. COOPER: I am unable to state the cost at the present time or even the pre-war cost. My only information on that point is the figures taken *en bloc* from the American report. Possibly, however, I may be able to reply to Mr. Sneddon more fully at a future meeting.

Dr. HENRY BRIGGS (Edinburgh): We are looking for a safe and serviceable lamp for rescue purposes, and this lamp seems to meet the requirements. It certainly is a very good lamp, and possesses all the advantages that Mr. Cooper claims for it. Instead of taking the cable over the head, I think it might be a better arrangement if it were carried round the sides of the cap. That would prevent its being knocked when anyone accidentally struck the roof.

The further discussion of the paper was adjourned.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM JAN. 26TH, TO MARCH 1ST, 1919, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of Week.	Day of Month.	Magnetic character.	0h. to 2h.	2h. to 4h.	4h. to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h.	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
			14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14 +
Sun. ...	Jan. 26	0	44′·0	44′·0	44′·5	44′·5	44′·0	46′·5	49′·0	47′·5	45′·5	45′·5	44′·5	43′·0	45′·5
Mon. ...	27	0	44·5	45·0	44·5	44·0	42·5	44·5	47·5	47·0	45·5	45·0	44·5	44·0	45·0
Tues. ...	28	1	43·5	44·5	45·0	44·5	44·5	47·0	49·5	50·0	46·5	44·0	40·5	41·5	45·0
Wed. ...	29	1	40·0	42·0	43·5	43·5	43·5	47·0	49·5	48·0	46·0	45·0	45·0	42·5	44·5
Thur. ...	30	0	44·0	45·0	45·0	44·0	43·5	47·0	50·5	51·0	48·5	46·0	45·0	43·5	46·0
Fri. ...	31	2	43·5	42·5	43·5	43·5	44·0	48·5	50·5	48·0	47·0	36·5*	38·0*	37·0*	43·5
Sat. ...	Feb. 1	2	40·5*	48·0*	47·0	47·0	45·5	47·0	49·0	45·5	42·0	43·0	43·0	43·5	45·0
Sun. ...	2	2	44·5	45·0	45·0	46·0	44·5	48·0	50·0	46·5	39·0*	42·0*	41·0	42·0	44·5
Mon. ...	3	1	43·0	47·0	47·5	46·0	46·0	46·5	47·0	46·0	44·5	44·0	41·5	42·5	45·0
Tues. ...	4	1	45·0	46·5	44·5	44·5	42 5	47·0	52·0	48·0	41·5	43·0	42·5	42·0	45·0
Wed. ...	5	1	42·0	44·0	47·5	46·0	46·0	47·5	49·0	45·5	45·0	40·0	44·0	44·5	45·0
Thur. ...	6	1	45·0	45·5	44·0	45·5	48·0	50·0	48·0	46·0	45·0	45·5	42·0	41·5	45·5
Fri. ...	7	0	44·5	44·5	44·5	44·5	45·0	46·5	47·5	46·0	45·0	44·5	44·0	44·5	45·0
Sat. ...	8	0	44·5	43·5	44·0	43·5	44·0	47·0	48·0	46·0	45·0	45·5	44·5	44·5	45·0
Sun. ...	9	0	44·0	44·0	43·5	43·0	44·5	47·0	48·5	47·0	45·5	43·5	41·5	43·0	44·5
Mon. ...	10	0	44·5	45·0	44·0	43·0	43·0	46·0	48·5	47·0	45·0	44·0	43·5	43·5	45·0
Tues. ...	11	0	44·5	45·0	43·5	43·0	42·5	45·0	46·5	46·0	45·0	43·5	43·5	44·0	44·5
Wed. ...	12	0	44·5	44·5	44·0	43·0	42·5	46·0	48·0	45·5	45·5	45·0	44·0	44·0	45·0
Thur. ...	13	2	44·5	44·5	43·5	43·0	45·0	47·0	49·0	50·0	52·0	49·5*	41·5*	38·5*	45·5
Fri. ...	14	2	37·5*	35·0*	40·5	43·0	45·0	47·0	48·0	47·5	42·5*	31·5*	41·5	43·5	42·0
Sat. ...	15	1	45·0	46·0	43·5	42·5	46·0	49·5	49·0	45·5	43·5	43·0	41·5	39·0	44·5
Sun. ...	16	1	41·0	44·5	43·5	44·0	46·5	47·5	47·0	47·0	41·5	44·5	39·5	41·5	44·0
Mon. ...	17	0	43·5	44·0	44·0	45·0	46·5	47·0	46·5	45·0	44·0	42·5	41·5	42·5	44·5
Tues. ...	18	1	43·5	43·5	43·5	44·0	44·0	45·5	47·5	45·0	44·5	43·0	44·0	41·5	44·0
Wed. ...	19	0	43·0	43·0	43·0	43·5	44·5	45·0	46·0	45·5	45·0	44·5	43·0	41·5	44·0
Thur. ...	20	0	41·0	41·0	40·5	42·5	45·5	48·0	48·0	47·0	46·5	44·5	44·0	42·5	44·5
Fri. ...	21	2	35·0	35·0	39·0	40·5	43·5	48·0	50·0	48·5	34·5*	35·0*	40·0*	43·5*	41·0
Sat. ...	22	2	48·0*	41·0	41·5	45·5	47·5	49·5	50·0	48·0	45·5	37·0*	40·0*	37·0*	44·0
Sun. ...	23	2	37·0*	42·5	42·0	45·0	47·0	51·0	50·5	47·5	45·0	37·5	38·5*	39·0*	43·5
Mon. ...	24	1	40·5	41·0	41·0	43·0	44·0	47·5	47·5	46·0	44·5	44·5	45·0	44·5	44·0
Tues. ...	25	0	43·0	42·5	41·5	42·0	43·0	46·0	48·5	46·0	44·0	44·5	45·5	44·5	44·5
Wed. ...	26	0	42·0	41·0	41·0	41·5	43·0	47·0	49·0	46·0	45·0	46·5	45·5	43·5	44·0
Thur. ...	27	1	42·5	40·0	39·0	41·0	43·5	47·5	48·5	47·0	46·0	47·5	48·5	44·0	44·5
Fri. ...	28	2	40·0*	36·0*	41·5*	48·5*	45·5	46·5	48·5	48·0	43·5	40·0*	42·5*	42·0*	43·5
Sat. ...	March. 1	2	46·5*	42·0	43·5	43·5	43·5	48·5	51·5	46·0	43·0	34·5*	41·5	43·0	44·0

Diurnal Inequality (i.e., departure from mean value for day).

	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.
February, 1918 ...	−1′·1	−1′·0	−0′·9	−0′·8	−0′·5	−1′·0	−1′·7	−2′·6	−2′·8	−1′·5	+0′·7	+2′·6
January, 1919 ...	−1·2	−0·8	−0·3	−0·4	−0·7	−0·3	−0·1	−0·9	−1·2	−0·1	+1·7	+2·7
January, 1918 ...	−0·9	−0·6	−0·2	+0·5	+0·2	−0·4	−0·9	−1·5	−1·8	−1·6	+0·5	+2·2

	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
February, 1918 ...	+3′·1	+3′·3	+2′·9	+1′·8	+1′·3	+0′·7	+0′·2	−0′·4	−0′·6	−0′·7	−0′·6	−0′·6
January, 1919 ...	+3·2	+3·2	+2·3	+1·7	+0·8	+0·1	−0·4	−1·2	−1·9	−2·3	−2·1	−1·6
January, 1918 ...	+3·1	+3·4	+2·4	+1·2	+0·4	+0·1	−0·2	−0·6	−0·9	−1·4	−1·7	−1·4

* Large disturbances during this interval.

Mean Value for Month.

February, 1918.	January, 1919.	January, 1918.
14° 53′·5.	14° 45′·4.	14° 54′·8.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G.M.T.

Character "0" means a day wholly free from any but small disturbances.

" "1" " " part or all of which is moderately or considerably disturbed.

" "2" " " part or all of which is highly disturbed.

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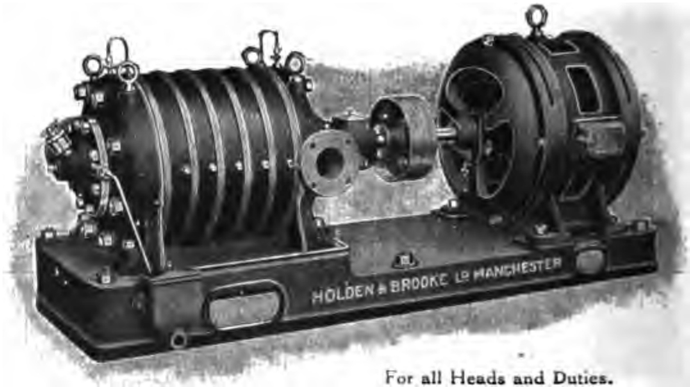
CENTRIFUGAL PUMPS



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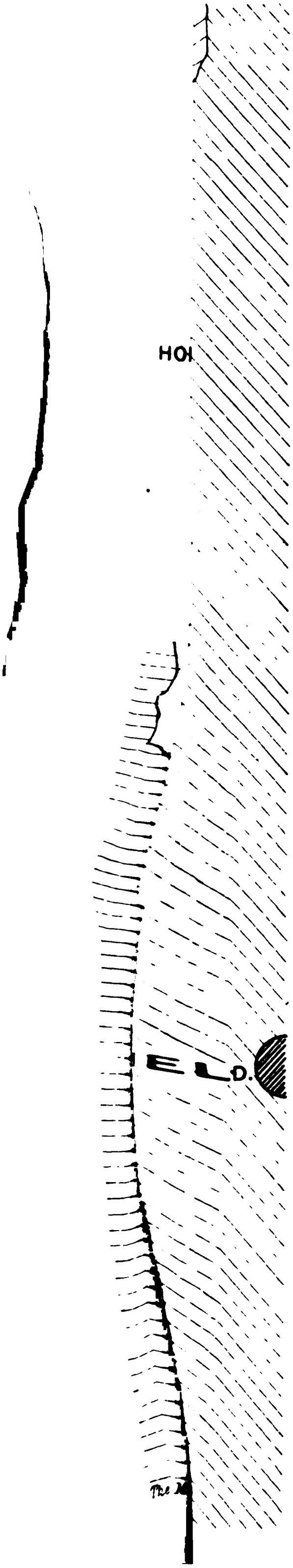

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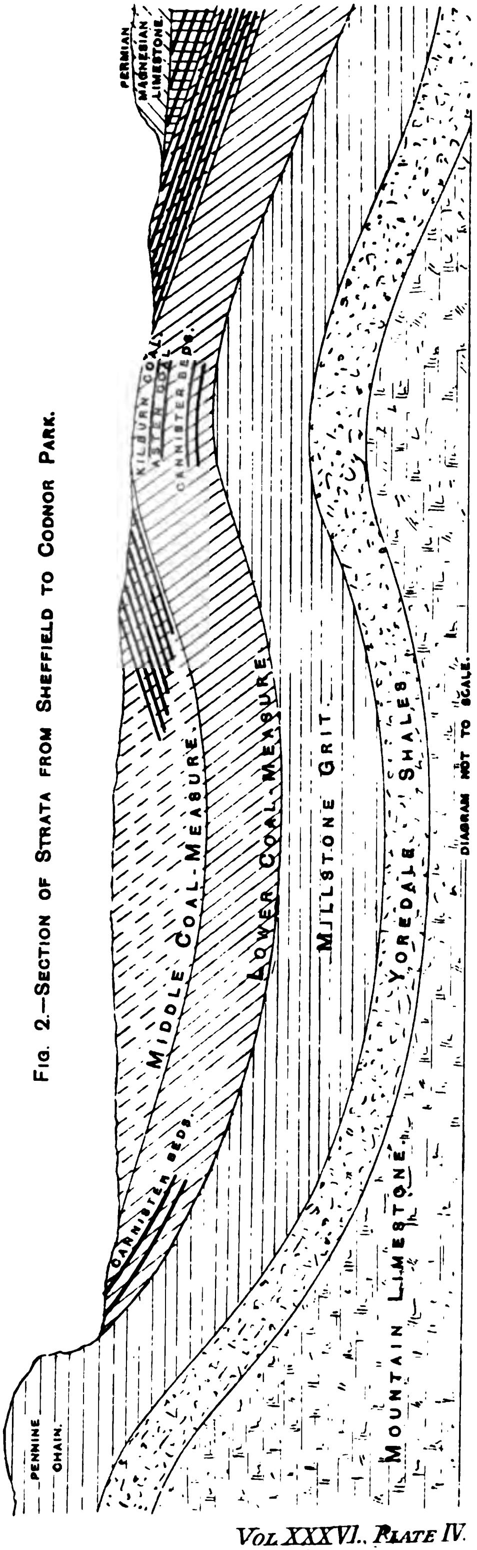

PERMIAN MAGNESIAN LIMESTONE.
KILBURN COAL
ASTON COAL
CANNISTER BEDS.
MIDDLE COAL-MEASURE.
LOWER COAL-MEASURE.
MILLSTONE GRIT
YOREDALE SHALES
MOUNTAIN LIMESTONE
CANNISTER BEDS
PENNINE CHAIN.
DIAGRAM NOT TO SCALE.

FIG. 2.—SECTION OF STRATA FROM SHEFFIELD TO CODNOR PARK.

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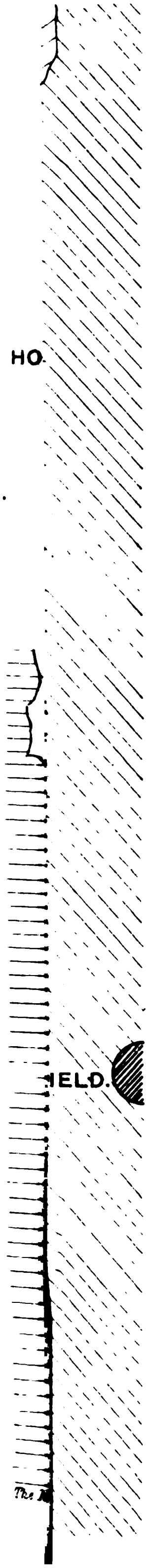
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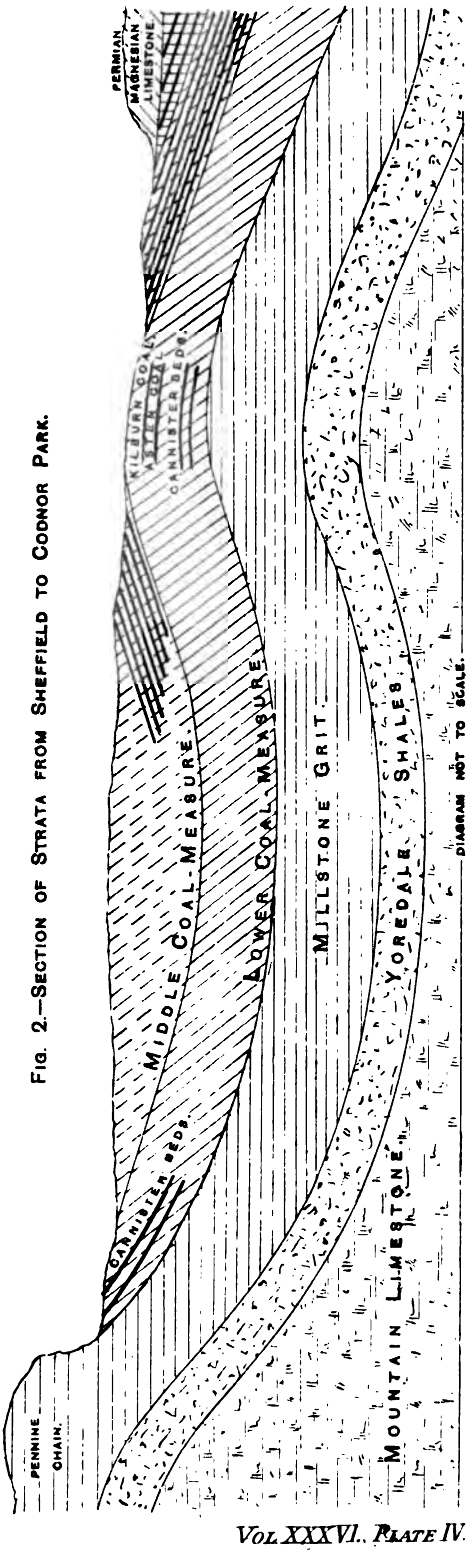
PERMIAN MAGNESIAN LIMESTONE
KILBURN COAL
ASTER COAL
CANNISTER BEDS
MIDDLE COAL MEASURE
LOWER COAL MEASURE
MILLSTONE GRIT
YOREDALE SHALES
MOUNTAIN LIMESTONE
CANNISTER BEDS
PENNINE CHAIN
DIAGRAM NOT TO SCALE

FIG. 2.—SECTION OF STRATA FROM SHEFFIELD TO CODNOR PARK.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM MARCH 2ND TO MARCH 29TH, 1919, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of Week.	Day of Month.	Magnetic character.	0h. to 2h.	2h. to 4h.	4h to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h.	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
	March.		14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14 +
Sun. ...	2	2	47'·0	47'·0	45'·5	45'·0	43'·0	45'·5	49·0	48'·0*	41'·5*	35'·5*	34'·0*	37'·5*	43'·5
Mon. ...	3	2	45·5	44·0	44·5	44·0	43·5	46·0	49·0	43·0*	40·5*	40·5*	43·5	44·0	44·0
Tues. ...	4	1	44·0	45·5	46·0	49·5	44·5	46·0	49·0	46·0	43·5	41·5	43·0	42·0	45·0
Wed. ...	5	1	44·5	44·5	44·5	43·0	43·0	47·5	49·0	47·0	44·0	43·0	40·0	34·5	44·0
Thur. ...	6	2	34·5*	42·5*	42·0	42·0	42·5	47·0	49·5	48·0	46·0	43·0	38·0	35·0	42·5
Fri. ...	7	1	36·0	39·5	42·0	43·5	42·0	46·5	48·5	47·0	44·5	42·5	42·0	42·5	43·0
Sat. ...	8	1	43·0	42·5	42·0	42·5	42·5	46·5	48·5	47·5	46·0	43·0	44·0	43·5	44·0
Sun. ...	9	0	43·0	42·5	43·0	42·5	41·5	—	—	—	—	—	—	—	—
Mon. ...	10	0	—	—	—	—	—	—	—	46·5	45·0	44·5	44·5	44·0	—
Tues. ...	11	0	43·5	43·0	42·5	43·0	43·0	46·0	48·5	47·5	45·5	46·0	44·5	43·5	44·5
Wed. ...	12	1	43·5	43·5	45·0	42·5	41·5	46·0	49·5	48·5	46·5	44·0	40·0	40·0	44·0
Thur. ...	13	1	42·5	43·0	42·5	41·0	40·5	46·0	48·5	48·0	46·0	45·5	42·0	37·5	43·5
Fri. ...	14	2	39·0	41·0	40·0	39·5	41·0	47·0	52·5	51·5	49·5	42·0*	41·0*	40·5	43·5
Sat. ...	15	1	42·0	42·5	43·0	41·0	41·0	45·0	47·5	48·0	47·0	46·0	42·5	42·0	44·0
Sun. ..	16	1	42·0	39·5	41·5	41·0	42·0	46·5	53·5	52·0	46·0	43·5	43·5	40·5	44·5
Mon. ...	17	1	35·5	35·5	37·0	42·0	41·0	47·5	49·5	47·0	44·0	43·5	43·5	42·5	42·5
Tues. ...	18	0	43·0	43·5	43·0	41·0	39·0	43·5	47·5	47·0	45·0	43·5	43·5	43·0	43·5
Wed. ...	19	1	43·5	43·5	43·0	41·5	39·5	44·5	49·5	50·5	50·0	45·5	44·0	38·5	44·0
Thur. ...	20	2	38·5	38·0	39·5	40·0	40·5	47·5	54·5	51·0	46·0*	37·5*	35·5*	32·0*	41·5
Fri. ...	21	2	38·0*	33·0*	41·5*	41·0	42·0	47·5	49·0	47·0	40·5*	38·0*	38·5*	40·5*	41·5
Sat. ...	22	2	38·5*	40·5*	43·0	43·0	44·5	49·5	53·0	49·0	40·5*	38·5*	39·5*	43·0*	43·5
Sun. ...	23	1	42·5	42·5	42·0	45·0	48·5	49·5	51·0	49·5	45·0	42·0	41·5	43·0	45·0
Mon. ...	24	0	42·5	42·5	42·5	41·0	40·0	45·0	48·5	47·0	44·0	43·0	43·5	43·0	43·5
Tues. ...	25	0	41·0	39·0	39·5	40·5	42·0	46·5	5 ·0	49·5	46·0	42·0	41·0	42·0	43·0
Wed. ...	26	0	41·0	40·0	41·5	40·0	38·5	44·0	50·5	50·0	45·5	43·5	43·5	43·0	43·5
Thur. ...	27	1	42·0	42·0	42·0	40·0	38·5	44·5	52·5	51·5	47·5	45·5	43·0	43·0	44·5
Fri. ...	28	2	42·5*	40·0	45·0	44·5	41·5	46·5	50·0	47·0	42·5	38·0*	36·5*	41·0*	43·0
Sat. ...	29	2	44·0*	46·5*	44·0	40·5	39·5	45·5	51·0	48·0	43·0	40·0	38·0	42·0	43·5

Diurnal Inequality (*i.e.*, *departure from mean value for day*).

	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.
March, 1918 ...	−0'·8	−0'·6	−0'·6	−0'·5	−0'·9	−1'·5	−2'·7	−3'·8	−3'·7	−1'·8	+1'·7	+4'·8
February, 1919 ...	−1·2	−0·9	−0·6	−0·8	−1·3	−1·2	−1·1	−0·8	−0·3	+1·1	+2·5	+3·5
February, 1918 ...	−1·1	−1·0	−0·9	−0·8	−0·5	−1·0	−1·7	−2·6	−2·8	−1·5	+0·7	+2·6

	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
March, 1918 ...	+6'·1	+5'·5	+3'·7	+1'·9	+0'·6	+0'·3	−0'·3	−1'·5	−2'·1	−1'·9	−1'·2	−0'·7
February, 1919 ..	+3·7	+2·8	+1·5	+0·6	−0·1	−0·2	−0·3	−0·7	−1·1	−1·6	−1·7	−1·6
February, 1918 ..	+3·1	+3·3	+2·9	+1·8	+1·3	+0·7	+0·2	−0·4	−0·6	−0·7	−0·6	−0·6

* Large disturbances during this interval.

Through stoppage of the clock, there was no satisfactory record from 10h. on the 9th to 13h. on the 10th. The interval was apparently quiet, and the results given for the 11th are probably closely applicable to the missing hours.

Mean Value for Month.

March, 1918.	February, 1919.	February, 1918.
14° 53'·5.	14° 44'·5.	14° 53'·5.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G. M. T.

Character "0" means a day wholly free from any but small disturbances.
,, "1" ,, ,, part or all of which is moderately or considerably disturbed.
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The above values were obtained from measurements made after "smoothing" the curves.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM MARCH 30TH TO APRIL 26TH, 1919, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of Week.	Day of Month.	Magnetic character.	Intervals in hours (Greenwich mean time). 0h. to 2h.	2h. to 4h.	4h. to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h.	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
			14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
	March														
Sun. ...	30	1	41′·0	43′·5	42′·5	40′·6	40′·0	46′·5	52·0	49′·5	43′·5	43′·0	42′·5	45′·5	44′·0
Mon. ...	31	1	46·5	42·0	42·5	41·5	40·0	47·0	52·0	50·0	44·5	41·5	40·5	40·0	44·0
	April														
Tues. ...	1	1	42·5	43·0	42·5	41·5	41·0	47·5	51·0	48·0	45·0	42·0	39·5	43·0	44·0
Wed. ...	2	0	44·0	44·0	42·0	39·5	38·5	46·0	51·5	49·0	44·5	43·0	42·5	42·5	44·0
Thur. ...	3	0	43·0	43·0	42·5	40·0	38·5	44·0	50·5	50·5	46·5	45·0	43·5	42·5	44·0
Fri. ...	4	0	42·0	42·5	45·0	44·0	41·0	43·5	48·5	48·5	45·0	43·0	43·0	42·0	44·0
Sat. ...	5	0	42·0	42·0	43·0	40·5	38·5	43·5	47·5	48·5	46·0	44·0	43·0	42·0	43·5
Sun. ...	6	2	42·0	42·5	43·0	41·0	41·5	47·0	52·5	51·0	46·5	44·5	44·0	36·5*	44·5
Mon. ...	7	2	32·5*	40·0*	44·5	45·5	45·0	46·0	49·0	47·0	44·0	43·0	37·5*	31·5*	42·0
Tues. ...	8	1	35·5	37·0	40·0	38·0	40·0	48·0	50·5	47·5	44·5	42·5	40·5	40·5	42·0
Wed. ...	9	1	41·0	39·5	41·0	40·5	39·5	44·5	49·5	48·5	45·0	43·0	39·5	37·0	42·5
Thur. ...	10	1	37·5	38·0	41·0	40·0	39·5	44·0	48·5	47·0	43·0	41·5	42·0	39·0	42·0
Fri. ...	11	0	41·0	39·5	40·5	39·5	40·5	46·5	51·5	50·5	45·0	42·5	42·5	41·0	43·5
Sat. ...	12	0	39·0	38·5	39·0	38·5	40·0	45·5	53·5	54·0	48·5	43·0	41·0	41·5	43·5
Sun. ..	13	0	39·5	39·5	41·0	39·0	38·5	43·5	48·0	48·0	46·0	44·5	42·0	42·5	42·5
Mon. ...	14	0	43·0	42·0	41·5	39·0	39·5	45·0	49·0	47·5	44·0	42·5	43·0	42·5	43·0
Tues. ...	15	0	42·5	42·0	41·0	38·5	38·5	45·0	50·0	48·0	45·0	44·0	42·5	40·0	43·0
Wed. ...	16	1	41·5	39·5	39·5	38·0	39·0	48·5	51·0	54·0	48·0	39·5	32·0	35·5	41·5
Thur. ...	17	2	36·0	36·5	36·5	35·5	41·0	51·0	52·0*	49·5*	41·0*	35·5*	35·5*	41·5*	41·0
Fri. ...	18	2	45·0*	45·0*	42·5*	42·0*	41·0	44·5	50·0	49·5	44·5	42·5	37·5	40·0	43·5
Sat. ...	19	1	42·5	40·5	39·5	39·5	39·5	44·5	47·5	46·0	43·5	40·5	41·5	40·0	42·0
Sun. ...	20	1	38·5	39·0	41·0	39·5	39·0	44·0	48·0	46·5	43·5	41·5	35·5	37·5	41·0
Mon. ...	21	1	42·5	41·5	39·0	38·0	40·0	46·5	48·5	47·0	44·5	40·5	38·5	39·0	42·0
Tues. ...	22	1	37·5	37·5	38·0	39·0	40·0	46·5	49·0	48·0	45·0	42·5	40·0	35·0	41·5
Wed. ...	23	1	38·0	40·0	40·5	38·5	40·0	46·5	51·5	50·0	46·0	42·5	43·0	42·5	43·0
Thur. ...	24	1	43·0	42·5	41·0	39·0	39·0	43·0	47·5	46·5	44·0	40·0	41·0	42·0	42·5
Fri. ...	25	0	42·0	42·0	41·5	40·5	40·5	43·0	45·5	45·0	44·5	43·0	43·5	43·0	43·0
Sat. ...	26	0	42·5	41·5	39·5	38·0	39·5	43·0	47·0	46·0	43·5	43·0	43·5	43·0	42·5

Diurnal Inequality (*i.e., departure from mean value for day*).

	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.
April, 1918 ...	−0′·5	−0′·8	−0′·6	−1′·6	−2′·2	−3′·0	−4′·5	−5′·7	−4′·8	−1′·7	+2′·2	+5′·1
March, 1919 ...	−2·3	−2·5	−2·2	−2·2	−1·9	−1·4	−1·8	−3·1	−3·2	−0·9	+2·2	+4·8
March, 1918 ...	−0·8	−0·6	−0·6	−0·5	−0·9	−1·5	−2·7	−3·8	−3·7	−1·8	+1·7	+4·8

	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
April, 1918 ...	+6′·8	+5′·9	+4′·0	+2′·2	+1′·0	+0′·1	+0′·2	+0′·1	−0′·4	−0′·5	−0′·7	−0′·7
March, 1918 ..	+6·8	+6·2	+5·0	+2·9	−1·6	+0·7	−0·3	−0·7	−1·3	−1·8	−2·0	−2·0
March, 1919 ...	+6·1	+5·5	+3·7	+1·9	+0·6	+0·3	−0·3	−1·5	−2·1	−1·9	−1·2	−0·7

* Large disturbances during this interval.

Mean Value for Month.

April, 1918.	March, 1919.	March, 1918.
14° 52′·2.	14° 43′·9.	14° 53′·5.

REMARKS.

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The above values were obtained from measurements made after "smoothing" the curves.

THE MINING INSTITUTE OF SCOTLAND.

FORTY-SECOND ANNUAL GENERAL MEETING,

HELD AT THE ROYAL TECHNICAL COLLEGE, GLASGOW, APRIL 5TH, 1919.

MR. DAVID M. MOWAT, RETIRING-PRESIDENT, IN THE CHAIR.

Mr. Robert McLaren, M.P., was unanimously elected as President for the ensuing year.

THE COAL INDUSTRY COMMISSION.

The RETIRING-PRESIDENT (Mr. D. M. Mowat): I think, considering the times, we have reason to congratulate ourselves. It is satisfactory to know that we have come through the trying period of the war so well as we have done, both financially and in respect of membership.

Since the last meeting of the Institute, events have transpired which will probably have a very marked effect on the coal industry with which we are so closely associated. On the demand of the Miners' Federation of Great Britain for an immediate advance of 30 per cent. on wages, a reduction of the statutory working day from eight hours to six, and nationalization of the mines, the Government appointed a Commission to enquire and report. The Commission consisted of twelve members, presided over by Mr. Justice Sankey, G.B.E. The Miners' Federation were allowed to nominate six members, three were nominated by the coal-owners, and the remaining three members were Mr. Arthur Balfour, at one time Master Cutler of Sheffield; Sir Arthur Duckham, K.C.B., engineer; and Sir Thomas Roydon, Bart., M.P., a shipowner and deputy-chairman of the Cunard Company. As the miners threatened to strike on March 15th, it was resolved to proceed first with the questions of hours and wages and to report on these matters by March 20th. The Commission sat continuously from March 4th to 17th and reported, as promised, on the 20th. There were three separate reports, one by the Chairman and the three independent members, one by the six nominees of the Miners' Federation, and a third by the three coal-owners' representatives. The first of these reports was adopted by the Government, as Mr. Bonar Law said, in the spirit and in the letter. It is with this report that I propose to deal very shortly. On the two questions specially before them, this report recommended (1) an advance of 2s. per day, and (2) the reduction of the statutory working day from eight to seven hours. Whatever opinions may be formed as to the policy of these decisions, in my opinion they cannot be seriously challenged. In comparison with other workers during the war, the miners have not been profiteers; and when engineers and many other surface workers have had their week's work reduced to 47 hours, it is only just that miners working underground should also have their day's work shortened by a similar amount. I express no opinion as to the wisdom of this policy at this stage, but as the Government has now adopted it, we can only hope the end will be satisfactory.

When, however, we consider the further recommendations in this report, the results are startling. If these were considered judgments, after full weight had been given to all the evidence which could be put forward on the subjects, we would not have much reason for congratulating ourselves either as coal-owners or as managers. That such recommendations should have been made at such a critical time without full investigation is little short of a crime. On what evidence were such recommendations made? The Secretary of the Commission in a letter dated February 27th, 1919, to the Coal-owners' and Miners' Associations wrote:—

> "I am directed by the Chairman of the Commissioners to inform you that he desires your Association to send one witness to give evidence before the Commissioners upon the first part of their inquiry, which it is intended to conclude by 20th March. That part of the inquiry will be confined to a preliminary investigation into the questions of wages and hours. . . . I should make it clear in the first instance that what you are now being asked to do is merely to provide evidence of a preliminary character, and that a further opportunity will be accorded to you in the later stages of the inquiry to supplement that evidence and to deal with matters which are not immediately germane to this part of the inquiry."

Both the coal-owners and miners were emphatically requested to confine themselves in the first place to the questions of wages and hours. The owners' witnesses obeyed this request, while the miners' witnesses gave practically no evidence on wages and hours, but spent most of their time on housing and nationalization. It should be observed that it was the Chairman who laid down the ruling that the evidence was to be confined to wages and hours, but he did not prevent the miners' representatives on the Commission from travelling very far afield from these subjects. Such action does not give one confidence in the final result. Sir Richard Redmayne was the witness who chiefly condemned the present system. The full print of the evidence is not yet procurable, but in the *Scotsman* he is reported to have said:—

> "That the present system of individual ownership of collieries is extravagant and wasteful, whether viewed from the point of the coal-mining industry as a whole or from the national point of view is, I think, generally accepted. . . . This is a somewhat daring statement, but I am prepared to stand by it."

The amount of reliance which may be placed on his evidence may be gauged by the value of the statement he made—that the miners' effective working day at the face is seven hours 37 minutes. I am sure you will agree with me that that estimate is grossly overstated, and that any deduction as to the probable reduction of output based thereon must be much too low and consequently dangerously misleading.

One turns with pleasure from such a condemnatory recommendation to the remarks made at the June meeting of The Institution of Mining Engineers in 1918 by Sir Henry Cunynghame, K.C.B., for many years permanent Under Secretary of the Mines Department of the Home Office, when he said:—

> "The point to which he wished to bear the most emphatic testimony, after many years' experience of coal-mines and coal-owners, was that he had found the coal-owners of Great Britain second to none in their determination to make sacrifice of money, industrial sacrifices, and sacrifices of of the organization of their mines, if once they could be persuaded that it really was for the good of the health of the working-man and was a practical system and not a mere fad."*

Sir Henry certainly had a much more intimate knowledge of the subject than the Commissioners who so promptly condemned the coal-owners.

Reading the newspapers during the sitting, two impressions were created, one that during the coal control the coal-owners plundered the nation, and the other that the miners lived in hovels. These are not quite subjects for discussion by this Institute, but I should like to say a word in this connexion. Statements were put in by Mr. Dickinson, Chief Accountant to the Coal Controller. These applied to the quarters ending March 31st, June 30th, and September 30th, 1918. The total profit per ton of coal raised in the United Kingdom during these periods was 1s. 9·6d., 1s. 8·57d., and 3s. 6·61d. respectively, and for Scotland the figures were 1s. 4·6d., 1s. 5·23d., and 2s. 7·5d. The higher figures in the September quarter were due to the increase in June and July of 4s. per ton in the price of coal, and probably to an increase in the percentage of coal shipped at high prices to neutrals. But, on analysis, it will be found that little of this apparently huge profit of 3s. 6·61d. found its way into the pockets of the coal-owners.

It was stated by Dr. Stamp, of the Inland Revenue, that the average profit over the whole coal-trade in the pre-war standard years of 1912 and 1913 was 1s. 4½d. per ton. Deducting this amount from 3s. 6·61d., an excess war profit of 2s. 2·11d. per ton is left. But this does not go to the coal-owner. Mr. Dickinson admitted that 80 per cent. of it, or 20·89d. per ton, went to the Treasury as excess profits duty. 15 per cent. of it, or 3·92d. per ever opinions may be formed as to the policy of these decisions, in my opinion they cannot be seriously challenged. In comparison with other workers during the war, the miners have not been profiteers; and when engineers and many other surface workers have had their week's work reduced to 47 hours, it is only just that miners working underground should also have their day's work shortened by a similar amount. I express no opinion as to the wisdom of this policy at this stage, but as the Government has now adopted it, we can only hope the end will be satisfactory.

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., page 274.

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* *Trans. Inst. M. E.*, 1917-1918, vol. lv., page 274.

With regard to the question of housing, no one believes that the present condition of housing is satisfactory or defensible. Is there any obligation on colliery-owners to provide houses for their workers any more than on steel-makers, engineers, shipowners, or lawyers? Miners' housing is only part of the great national housing question. The prominence which miners' housing has received in this report conveys the impression that the health of the occupants of the average miner's home is far below that in the average worker's home. So far as Scotland is concerned, that is not so.

Mr. Justice Sankey said that the preliminary report would deal with wages and hours only, yet he and his three colleagues have included in their report recommendations on the system of private ownership, management, housing, etc., issues on which evidence was specifically ruled out of order by the Chairman in his invitation to the coal-owners.

It is most unfortunate that the Commissioners have apparently in such an unfair way made recommendations of such importance, and as a protest against such action I would ask you to support the following resolution:—

> **"That the members of the Mining Institute of Scotland, assembled at their Annual Meeting, protest against the action of the Chairman and certain members of the Coal Industry Commission in condemning the coal-owners and the mining profession with regard to the system of working in the coal industry without full inquiry."**

I think the coal-trade has been grievously maligned. For example, I have been talking to a number of outside people, and I find everyone of them has an entirely wrong impression of the effect of the evidence given. Only parts of the evidence can be shown in the newspapers, and the corrections made in cross-examination do not come out. You may take it that the people who represented us in London put up the best fight they could, and matters were not quite so black as would appear from a perusal of the newspapers. At the same time, I adhere to what

I have said about the unfairness of the methods. I think that is the view of most people who have any knowledge of what actually took place.

Mr. James Hamilton (Glasgow): I agree with everything that the President has said, and I have pleasure in seconding the resolution. It is unfortunate that the evidence as taken is not available. It is rather an extraordinary thing that it should be so, because I understand the usual practice in such circumstances in the past has been to publish the evidence day by day *in extenso*, and to make it available to every person who was interested enough to purchase a print of the proceedings. That has not been done on this occasion. The resolution strongly condemns the Chairman and certain others. Judging from the evidence given in the newspapers, the Chairman of the Commission (Mr. Justice Sankey) is the most responsible party. He allowed evidence to be taken which had really no bearing on the question; and in saying so, I am allowing him the widest interpretation possible on the remit. The Chairman almost seemed to be lacking in backbone. On one particular point I noticed he agreed under pressure from one of his colleagues to reconsider his decision on a point of procedure twice over. I did not see what happened after the third decision. It almost seemed as if he had no mind of his own on the matter beyond reporting by March 20th. One cannot help the suspicion that the report was to order. The sting of the report seems to me to lie in the phrase "the present system stands condemned." What is meant by that I really do not know, and no one appears to know, unless possibly the Chairman himself. There is nothing in the evidence as it appeared in the press to justify such a statement, and it is most regrettable that it should have been made. Further, the suggestion that there should be some change in the management of the collieries, or, rather, that the workers should be given some effective voice in the management of them, is far beyond what the Commissioners had any evidence to justify, and one exceedingly difficult to give effect to. It is, perhaps, not surprising as coming from the Chairman, but what of the three business men who supported him? They at least ought to have known better.

The resolution was put to the meeting, and unanimously agreed to. It was further agreed that a copy of the resolution and Mr. Mowat's remarks should be forwarded to the Prime Minister and to Members of Parliament.

The Newly-elected President, Mr. **Robert McLaren**, M.P., then took the chair, and delivered the following Address:—

PRESIDENTIAL ADDRESS.

THE INDUSTRIAL UNREST OF THE PRESENT DAY.

By ROBERT McLAREN, M.P.

I need scarcely say that I have undertaken the important duty now placed upon me with great fear and trembling. I pointed out to the Council when they proposed to nominate me as President of the Institute that since I had now become a Member of Parliament, it would be impossible for me to discharge thoroughly the duties of President. I am very glad to say that the Council undertook, if I would just do my best, to give me all the assistance they could. Will you permit me at the outset to thank you for electing me as President of the Institute for the second time. To me the honour is all the greater because I am succeeding as President a very old and valued friend. We have known each other for a long time, and there is this about Mr. Mowat, the longer we know him the better we like him. I am glad you have passed that resolution to-day on the subject of the Coal Industry Commission. Let me say this that the opinion of the more responsible men in the House of Commons is that Mr. Justice Sankey went beyond his remit. At the same time, it is quite true, as Mr. Mowat has stated, that a bad feeling and impression was created by the evidence of the last witness, especially in connexion with the question of housing. That evidence was given in a most awful tone, and the state of nerves in which the witness appeared to be was enough to move the Commissioners to tears. Be that as it may, it is up to you now to see that the coal-owners and managers get fair play in whatever may yet fall to be done.

I am not going to give you to-day a scientific Address. I am going to speak on a somewhat unusual subject, namely, "The Industrial Unrest of the Present Day." At the present time, there is almost universal unrest among the industrial classes, and it is my purpose in addressing the members of the Institute to examine the various reasons assigned for this disquietude.

The unrest to begin with had its origin during the course of the war: as the war progressed, all classes of workpeople engaged in making munitions, directly or indirectly, began to realize that if the war was to be prosecuted to a successful termination munitions were absolutely necessary; and having been convinced of the fact, they asked for higher wages in the form of war bonuses. Part of this was due to an increase in the price of food-stuffs. As wages increased, the necessaries of life and materials increased in price, and fresh demands were constantly made on the Government, who had assumed full control of industries. The Government did nothing to keep down expenditure or wages, but, on the contrary, appeared to encourage it, and this was shown by the fact that the Minister of Munitions gratuitously advanced the wages of a section of munition workers, with the result that all the other sections clamoured for the same terms—and who could blame them?

Various reasons are given for the state of matters prevailing among the industrial classes. The Prime Minister, speaking in the House of Commons on February 11th, 1919, about special war conditions which conduced to the unrest, stated: "There is the strain of the last four-and-a-half years. . . . There is no doubt that nerves are rattled." That there was a strain on the nerves during the period of the war no one will deny, but the strain and anxiety was not confined to one class: what about the strain on the nerves of the large body of workpeople who were in charge of the industrial operations, and whose period of mental strain continued for longer stretches than the workers, and of those on whom the whole responsibility for the output of munitions rested? It was infinitely greater. Among the latter classes there has been no unrest; and, in view of the fact that those classes had if anything much greater strain to the nerves than the ordinary workers, and have shown no sign of unrest, I do not think that the cause of "rattled nerves" described by the Prime Minister is a legitimate one.

The housing question is also given as a cause. The dearth of suitable houses in the whole country is very acute, and the condition in which the country finds itself can be traced to rash legislation. The result of that legislation was to arrest building of houses by private enterprise, and finally to stop building operations. During all the years that houses have been scarce there was no industrial unrest, and to say now that the want of housing is a cause of the unrest is beside the mark.

One cause for which I think there is some justification is unemployment. In the mind of the honest workman is a genuine fear of lack of employment: to anyone who has experience in the matter it is one of the things the very thought of which casts a gloom over a man's home, and any scheme which can be devised in a legitimate way should be heartily approved. The question of reconstruction is looming largely, and the Government is at present engaged in thinking out various methods by which constant employment can be given to the workmen engaged in the various industries. It is evident, if a scheme is to succeed, that to enable the industries of the country to be kept fully employed, it can only be by an increased output in manufacture, and anything that would tend to retard increased production would have most disastrous consequences. By increased production the wages of the workmen would be kept up, and above all the cost of the articles would be reduced, thereby permitting the manufacturer to compete successfully against his rivals in the markets of the world. The American nation is a good example of the benefits of large production. Take the coal-trade, which interests us as a Mining Institute most. Due to several causes favourable to them, the average output per person employed is about four times greater than in Great Britain; the cost of raising is less than half that in this country; and due to this large production and decreased cost the American coal-owner is just now capturing markets which have long been held by this country. What is true of coal is equally true of steel and other manufactured articles. The remedy to secure steady employment and good wages is increased production, and when the lurking dread of unemployment has passed, the unrest caused by it will vanish.

The high price of food and the necessaries of life is stated to be a cause of the unrest. Much has been said in condemnation of the profiteer, and in many instances the condemnation has been justified; but the workman did not suffer on account of the high cost of food, as his wages in most cases were raised commensurate with the increase in food, and those who suffered were the professional and middle classes whose incomes were stationary. The view, therefore, that the high cost of food is a cause of the unrest is not accurate.

There are in my opinion two chief causes at the bottom of the unrest—the prospect that now that hostilities have ceased the war bonus may be withdrawn and incomes reduced, and the spreading of revolutionary doctrines among the unthinking and irresponsible classes of the community. The human element enters largely into the first matter. No one likes the prospect of a reduced income, and I am not going to blame the workman altogether for what is after all quite a human attitude. I am, however, going to blame the authorities for permitting a system to grow up which is wrong in principle and manifestly unfair to a very large body of citizens who were not in a position to resist, but had to bear the unfair burden imposed upon them. I refer to those alluded to already, the professional and middle classes who were during the period of the war "silent sufferers."

The other cause of the unrest is the pernicious doctrine being promulgated by a small but active class of men, who openly state that they are out for revolution, who denounce capitalists as if they were the parasites of humanity, who are bent on destroying society, have no regard to sanctity of contract or honour, and whose aim is destruction of all government, by whose sedulous teaching the minds of men are diverted from a path of rectitude and led to believe that it is right and proper to take possession of a man's property without payment. The Government of this country should take the necessary steps, by propaganda or otherwise, to counteract the teaching done openly before it is too late. It is our duty as responsible citizens and members of the community to show what a man's duty is to the State.

As to how the present unrest is to be allayed is a difficult problem. Perhaps I might be permitted to say that there appears to me one way in which it may be solved, namely, mutual confidence between employers and employees, and a display of sound common sense. It should frankly be stated that all employers are not saints, nor are all employees saints; and just as there are some employers who are not a credit to their class, the same remark applies to some employees; but there are among both classes a big majority of honest men, who can view matters in a broad, sympathetic spirit, and whose desire is to be fair. Surely such can trust each other. Unless there be an honest belief in each other's rectitude, a belief that while each naturally looks to the interest of his class, yet not to take advantage, there is little hope of accomplishing the desired end. It is a source of regret that some employers still have a suspicion—and perhaps they have just reasons—of the genuineness of the promises made by the reputed leaders of the employees, and that, on the other hand—and for just reasons, too—the men's leaders, while speaking in quite a conciliatory strain, have shown a disposition to doubt the *bona fides* of the employers. If common sense could be exercised by both sides in trying to settle their differences, much good would result. I am confident that mutual confidence and common sense, combined with the best men on both sides, would result in the realization of peace and concord between the employers and employees in the industries of the country.

The discussion of various papers was adjourned.

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

Held at the Danum Hotel, Doncaster, April 5th, 1919.

Mr. W. D. LLOYD, President, in the Chair.

THE EFFECT OF COAL-MINING ON THE OVERLYING ROCKS AND ON THE SURFACE.

By W. D. LLOYD.

I.—Introduction.

In view of the great importance of this subject, both to those interested in the mining of coal and to the owners of surface property, it is felt that no apology is needed for bringing forward this paper, especially as it is some considerable time since any paper dealing with the subject has been presented.

The present unsatisfactory state of the law regarding the support of the surface has been caused largely by insufficient knowledge on the part of the legislature and the public generally of the probable effect which mining coal from seams of various thicknesses and increasing depths will have on the surface. That this lack of knowledge still exists is not to be wondered at, seeing the variety of opinions held and expressed by mining engineers in the past. That so much difference of opinion has existed and still exists is due principally to the fact that the subject is complex: so many factors have to be taken into consideration that unless due regard is paid to all those which are essential in any particular case, unreliable conclusions are arrived at.

Our knowledge of the subject would be increased by the publication of reliable data of all the essential factors concerning particular cases. My object in writing this paper is, after attempting to summarize briefly the theories which have been put forward and the opinions which have been expressed in the past, to indicate the lines along which further observations should be directed, with a view to inducing members to publish observations they have already made, and to take what little extra trouble is necessary to keep reliable records of the effect their mining operations have on the surface, so that in future, by a careful comparison of the results obtained, it may be possible to propound reliable theories; or, at any rate, so that mining engineers and the public also may be in a position to foresee, with greater accuracy than they can at present, what effect mining operations may be likely to have on surface works and buildings.

II.—SUBSIDENCE.

Supposing for a moment that all seams of coal lay perfectly horizontal, that it were possible to extract an entire seam without leaving anything in its place and without leaving any support at the edges of the area excavated, and that the superincumbent strata were one homogeneous and elastic mass which could gradually subside without breaking, the surface overlying the area removed would then gradually settle down or subside by an amount equal to the thickness of the seam extracted, and the question of subsidence would be comparatively simple.

Unfortunately, coal-seams lie at all angles from the horizontal to the perpendicular; in order to extract them in one operation, it is generally necessary to undermine the coal by excavating the underlying fireclay; the holings, with any bands of dirt interstratified with the coal, and also the roof which has to be taken down to make height and maintain the roadways, are packed into the goaf made by removing the coal. The overlying strata are not homogeneous, but consist of numerous kinds and thicknesses of strata, varying in hardness and consistency; they are broken by faults slips, and cleavage-joints, and sometimes one group of strata lies unconformably on another. The roof cannot settle down over a mined area without more or less disintegration, and it must bend or break at the perimeter of the mined area.

III.—AMOUNT OF SUBSIDENCE.

In longwall working it is generally assumed that the amount of surface subsidence will depend on the thickness of the material removed, measured by the total height of the working-face.

It is recognized that for an equal thickness extracted, and similar conditions of packing, the amount of subsidence will be more for shallow seams than for deeper ones, as the greater the depth the thicker are the strata which have to settle; and as the disturbed ground takes up more room than solid ground, it has been held by some that after a certain depth is reached no subsidence of the surface will be caused.

Allowance must therefore be made for the quantity and the quality of the packing-material. It is practically impossible to stow the goaf so tight as to afford the same support as was furnished by the virgin seam. By hydraulic stowing with sand, support may be obtained almost equivalent to that afforded by natural strata. The efficiency of hydraulic stowing ·depends on the quality of the material used and the amount of material it is possible to force into the vacant space before the roof subsides. This method is not generally applicable to longwall working, and so far has been but little practised in this country. The efficiency of hand-packing depends on whether rock or bind is used for walling, whether the packs are made as tight as possible at the top, whether wastes are left, and, if so, what proportion of space is occupied by packs and wastes respectively, and also whether the packs are kept up close to the face or are kept back a considerable distance. A factor which has some bearing on the amount of support afforded by packing is the nature of the underlying strata: if the floor is comparatively soft and yielding, the packs will be forced into the floor, which will rise or lift between the packs in the wastes and roads; and although this will tend to increase the amount of filling of the empty spaces, it will be done by disturbing an additional thickness of strata; the net extra subsidence will be equivalent to the depth the packs are pushed downwards, less the extra amount of support afforded by the increased filling of the waste spaces.

The capacity of the overlying rocks for bending or sagging without breaking must also be taken into consideration. Strata which break to pieces will obviously occupy more space than those which settle in large masses, and although the former will ultimately be compressed by the weight of the overlying rocks, even at extreme depths they will never be compacted into their original volume. In this connexion it is interesting to recall the conclusions arrived at by M. Fayol after numerous experiments and observations:—

> "1. That the ordinary stowing employed in mines of less than 1,000 metres deep, and consequently not subjected to a pressure of more than 250 kilogrammes [per square inch centimetre], always retains a certain increased volume.
>
> "It is difficult to have any exact data regarding the shrinkage of stowing in mines, on account of the irregularity of the excavations and the proportion of empty spaces which remain unfilled in spite of the utmost care. The ordinary materials (shale and sandstone) which are employed, after having undergone an increase of volume amounting to 60 per cent., appear to undergo a shrinkage of about 30 per cent. in mines between 100 and 300 metres deep, leaving them with a volume of about 12 per cent. greater than that of the compact rock from which they were obtained.
>
> "2. It would be necessary, in fact, to descend to a depth of 2,000 metres before the weight of the ground amounted to 500 kilogrammes per square centimetre."*

It may be recalled that Fayol found by experiment that broken shale still retained 110 per cent. of the volume of the compact rock after being subjected to a pressure of 500 kilogrammes per square centimetre, and that broken sandstone retained 120 per cent. of the volume of the compact rock under the same pressure. It is also obvious that the nearer the surface is approached the less becomes the pressure on the broken ground below.

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* As reported by Prof. W. Galloway, *Procs. South Wales Inst. Eng.*, 1896-1897, vol. xx., pages 319-320.

IV.—Extent or Amplitude of Subsidence.

Vertical Theory.—In early days and with more or less horizontal mines at comparatively shallow depths it was generally assumed that subsidence would take place vertically over the area worked, and that the strata would break off vertically at the edges of the excavation; but it has long been noticed that the surface area affected often exceeds the area mined.

Normal Theory.—Messrs. L. E. Young and H. H. Stoek published in 1916 their excellent treatise on "Subsidence resulting from Mining." Anyone interested in the subject of subsidence is recommended to refer to their work for a very complete *résumé* of the present knowledge of the subject, and I wish to express my indebtedness to it for considerable help in preparing this paper. They give the history of the "normal" theory as follows:—

> "Although credit for formulating the first theory of subsidence is usually given to the Belgian engineer, J. Gonot, it is claimed by L. Thiriart that the fundamental idea of the theory of the normal was first presented by the French engineer, Toillez, in 1838. Gonot studied surface subsidence in the vicinity of Liége in 1839, and formulated a theory which was published in 1858. He claimed that following the removal of coal the overlying strata would sink and the angle of fracture would be perpendicular to the plane of the coal bed. This theory was later referred to as the "Law of the Normal." Mining operators in general and many engineers criticised this theory and, while many later writers accepted the principle as it applied to horizontal and slightly dipping beds, various qualifications were suggested in regard to the angle of fracture of steeply inclined beds. Gonot also held that the break extends through to the surface, irrespective of the depth of mining. He based this theory on observations he had made on subsidence at Liége. The Belgian engineer, Recloux, who was appointed with Wellekens to investigate subsidence about Liége in 1858, called attention to the fact that Gonot's theory undoubtedly could not be applied to vertical and highly inclined beds."*

The theory was emphasized by M. G. Dumont in his report on subsidence round the town of Liége, published in 1871. Prof. Galloway, in reviewing M. Dumont's work, writes as follows:—

> "Unfortunately for the present purpose the question which he attempted to solve was complicated by the presence of old workings and by the existence of the workings of several mines all within a comparatively small area. He gives his unqualified support to the Theory of the Normal and endeavours to prove it by means of the facts at his disposal. He proves conclusively that in cases in which the seams were inclined the disturbance of the surface took place towards the dip of the seams, but his contention that it took place along lines normal to the dip is not altogether convincing, for the reasons given above."†

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* University of Illinos, Bulletin No. 91, 1916, pages 86-87.

† *Procs. South Wales Inst. Eng.*, 1896-1897, vol. xx., page 308.

J. Callon, of the École de Mines, Paris, in 1874 accepted the theory with the reservation that—

"when the coal bed is overlaid with unconformable beds the angle of fracture will extend through each bed perpendicular to its plane of bedding."*

The Dome Theory and "Harmless" Depth.—M. Fayol, Director of the Commentry Mines, France, in a paper communicated to the Société de l'Industrie Minérale in 1885 gave the results of his experiments and observations. After reciting some of the contradictory statements which have been expressed from time to time regarding the subject, he writes:—

"It is thus evident that opinions are greatly divided; these differences are, however, more apparent than real; they are the result of generalising from single facts which are only particular cases of the following rule:—

"The movements of the ground are limited by a kind of dome which has for its base the area of the excavation; their amplitude diminishes by degrees as they extend further away from the centre of that area."†

Amongst others he gives a diagram (Fig. 1, Plate II.) which he states shows—

"how the position of the subsidence varies according to the depth of the excavations below the surface—and explains how observations which seem to be diverse from each other, and often contradictory, are not really so.

"*AB* is an excavation: *ABCD* the zone of subsidence.

"When *S* represents the level of the surface there is no appearance of subsidence.

"At the level S_1 there is a small subsidence limited on the right-hand side by the normal *BC*, drawn from the highest point of the excavation.

"At the level S_2 the limit of the subsidence on the left-hand side corresponds to the vertical *AD* drawn from the lowest point of the excavation.

"The limits of the subsidence coincide on the right with the vertical *BE* at the level S_3; on the left with the normal *AF* at the level S_4; and on the level S_5 with a line inclined at 49 degrees drawn from the lowest point of the excavation."‡

Prof. Galloway in his paper comments on M. Fayol's theory as follows:—

"M. Fayol's rule agrees with all the facts observed: absence of subsidence, more or less important subsidences, movements limited to the vertical above the perimeter of the excavation, those limited to the normal or to other inclinations, and so on. It has the disadvantage of being indefinite; but in a question which embraces so many elements, many of which are unknown or not well known, such as the nature of the rocks, the thickness of the beds, geological accidents, the action of water, etc., we cannot hope to arrive at absolutely accurate formulæ; we shall have already accomplished much when we get to know very nearly the true form, the direction and the relative amplitude of the subsidences, and are in a position to combat false ideas successfully."§

F. Rziha, a Vienna professor, in 1882 suggested a "dome" theory, and held that when mining is carried on at a great depth there may be no disturbance of the surface. He suggested that what he termed the "harmless" depth might be found by dividing the vertical seam thickness by the coefficient of the increase of the rocks when broken.

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* Young and Stoek, *loc. cit.*, page 89.

† *Procs. South Wales Inst. Eng.*, 1896-1897, vol. xx., page 310.

‡ *Ibid.*, page 342.

§ *Ibid.*, page 311.

This theory has not met with any support from mining engineers in this country, and seems to be founded on incomplete appreciation of essential factors. It is generally recognized that except where the area undermined is comparatively small the surface must ultimately be disturbed; at the same time, it should be noted that it is an established fact that subsidence may be so gradual and uniform that it is unnoticeable. For example, Mr. Tylden Wright stated that:—

> "He had had many cases in his experience where, instead of the surface subsiding regularly, there had been apparently no sign of subsidence on the surface. He knew workings in the South of England where large areas had been swept out under a city without the slightest perceptible subsidence having taken place. The same thing had also occurred in Derbyshire."*

Mr. J. A. MacDonald at the same time confirmed this experience by stating:—

> ". . . . . it was an interesting fact that in a city in the West of England the coal had been worked for a century and a half, and he believed probably longer, under parts of the city, without causing the slightest injury to any of the buildings."†

Mr. Joseph Dickinson, F.G.S., contributed two papers on "Subsidence caused by Colliery Workings" to the Manchester Geological Society, one in 1857 and the other in 1898. He accepted the "normal" theory with limitations.

> "The subsidence may be, and doubtless sometimes is, at a right angle to the dip—coinciding with the rule; but this happens only with strata of certain hardness and at a certain dip; and it would not so happen with them were they either harder or softer, or if the dip were either more or less. Up to a certain angle of dip, therefore, in estimating the probable extent of subsidence, additions to a right angle should be made; and when beyond the certain angle, deductions are required."‡

Mr. Dickinson suggested that "the direction of subsidence may be judged from the slopes taken by faults." He writes:—

> "The slope of a fault in horizontal strata averages about 1 in 3·07 from the perpendicular, varying, according to the hardness and cohesion of the strata, from about 1 in 5 in hard rock, to 1 in 3¾ in medium, and 1 in 2½ in soft.
>
> "According to the well-known rule, the slope of a fault indicates the direction of the throw. If the downward slope in horizontal strata be away from the perpendicular, the strata beyond are thrown down. The fault in inclined strata maintains the same angle across the bedding of the strata, but the relation of the slope to the perpendicular is changed, the slope becoming flatter with a downthrow to the rise and steeper with a downthrow to the dip. This variation of slope increases until at a certain inclination of strata a downthrow to the dip becomes perpendicular, and afterwards overhangs; a downthrow on the rise flattening proportionately. . .

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* *Minutes of Procs. Inst. C.E.*, 1898-1899, vol. cxxxv., page 128.

† *Ibid.*, page 129.

‡ *Trans. Man. Geol. Soc.*, 1896-1898, vol. xxv., page 587.

> "So likewise in certain aspects does the limit to which subsidence extends correlate with the slope of faults. The ground beyond apparently gives some support to the subsided part, and gravity partly counteracts overhanging in steep inclinations, thus causing the extremity of the subsidence to be less steep than the slope of a fault except with thick seams and soft strata; but in all other aspects, in all kinds of strata, the coindication is identical. The angles at which subsidence traverses the bedding of strata vary with the hardness, and the slopes deviate from the perpendicular according to the inclination of the strata, similar to those of faults."*

Mr. Dickinson's suggestion is worthy of careful consideration, but it must be borne in mind that, although it seems reasonable to expect that the stresses set up in mining operations and by natural settlements of the earth's crust act in similar ways, the resultant strains or fractures produced in the strata will vary in angle according to the various forces of which they are components, in the same way as the angle or hade of faults varies very considerably, as instanced in West Yorkshire, where some normal faults have a hade of 23 degrees, or 1 in 2·25 from the vertical, whereas others are extremely flat, lying at an angle of 53 degrees, or 1 in 0·75 from the vertical.

Mr. T. Forster Brown, in discussing Mr. S. R. Kay's paper, stated that a safe guide to the angle is the angle of faults in similar strata in the same locality.†

Mr. E. B. Wain, in taking part in the same discussion, stated—

> "It was not difficult to approximate the angle of repose in the coal measures of any district, as the line of fracture shown by the faults or natural breaks in the strata might generally be taken as a guide. The faults in the Midland coalfields showed approximately an angle of about 1 in 5 from the vertical line, and their line of fracture was irrespective of the plane of stratification."‡

It may be noticed that Mr. Wain does not agree with Mr. Dickinson that the hade of faults usually keeps the same angle with the stratification, though varying from the perpendicular. It would be interesting to have the opinion of some of our geological members on this point.

Mr. Dickinson in 1898, after reviewing the evidence given before the Royal Commission in 1868 and 1869, writes as follows:—

> "THE METHODS WHOLLY OR PARTLY AGREED UPON for computing the extent of ordinary subsidence and defining the areas for support, have been mainly derived from observations. The first process is to define the extent of the subsidence on all sides of the property to be protected, and from this to delineate by common projection the position and extent of the areas of coal requisite to be left for support. The extent increases in proportion to the depth, and varies considerably where the strata are inclined . . . . .
>
> FOR HORIZONTAL SEAMS, not exceeding 6 feet in thickness, and with strata of the average hardness of those in Lancashire, the ordinary

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* *Trans. Man. Geol. Soc.*, 1896-1898, vol. xxv., pages 600-601.

† *Minutes of Procs. Inst. C.E.*, 1898-1899, vol. cxxxv., page 152.

‡ *Ibid.*, page 169.

subsidence is taken as extending on all sides to 1-10th of the depth, and to this a margin is added. The margin is limited by some mining engineers to an additional 1-10th of the depth; but to this others add an arbitrary margin varying to 20 yards in width, for contingencies, and to keep subsidence away from the property to be protected . . . .

"Where the strata are softer, the extent of the subsidence alone is sometimes taken as 1-6th or even 1-4th of the depth to the working, whilst for the 10-yard seam and very soft strata of South Staffordshire it is taken as extending to half of the depth or more; one or both of the margins being added in each case.

"On the other hand, for hard siliceous rock such as that called quor in South Wales, and for beds of limestone as in parts of Northumberland, and for the partially stratified floating basalt of Scotland, reductions are needed.

"FOR INCLINED SEAMS, the lateral subsidence is taken to be the same as that for horizontal seams. but the rise and dip subsidences vary according to the inclination. The subsidence on the dip is always more than that on the rise, consequently a larger area for support is required at the rise side. This variation in size of the area is taken to increase only until the angle of rest is attained, after which at steeper inclinations increase ceases on the dip, and nearly all subsidence beyond the working ceases on the rise. With strata of average hardness and workings not exceeding 6 feet, this angle of rest is taken to begin at about the angle of 18 degrees from the horizontal, or an inclination of 1 in 3·07; above which it remains without further change to the angle of 72 degrees, when decrease from the maximum begins and continues up to the perpendicular. . . . .

"The measure of the distance to which subsidence extends on the dip until the angle of rest is attained, when further increase ceases, is commonly taken to be 1-10th of the depth added to the horizontal distance between the points of intersection of the seam by two lines diverging from the nearest edge of the property to be supported, one of the lines being perpendicular and the other a rectangle to the inclined plane of the seam.

"In measuring this depth of which 1-10th is taken for defining the rise side of the area for support, some engineers take the vertical distance from the nearest part of the surface to the rise side of the area, but others take the longer distance from the edge of the property to be protected down to the seam; the difference in the length of the two lines with a seam lying at 18 degrees being as 0·95106 is to 1·0.

"For defining the dip side of the area, the depth of which 1-10th is taken being further on the dip is, of course, always more than that for the rise side.

"Another difference sometimes occurs in this computation; some consider that all needful margin is included in the 1-10th of the depth combined with the distance between the intersection by the two lines, especially when the 1-10th of the longer line is taken; but others add an arbitrary margin, varying up to 20 yards, for contingencies and to keep subsidence away from the property to be supported, as shown in the diagrams.

"For softer strata and thicker seams, particularly with such as the 10-yard seam and very soft strata of South Staffordshire, proportionately increased modifications are required.

"For the hard rocks in South Wales, Northumberland and Scotland, described under the heading for horizontal seams, proportionate reductions are required."*

I have given this somewhat lengthy extract from Mr. Dickinson's paper, as it appears to me to be perhaps the clearest published statement of the views held with regard to the amplitude of subsidence and the extent of "pull-over" by mining engineers in this country at the beginning of this century.

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* *Trans. Man. Geol. Soc.*, 1896-1898. vol. xxv., pages 602-605.

Theory of Normal Obliquity.—Mr. H. W. G. Halbaum in 1904 premised that—

> "the force of the total roof-action was the oblique resultant of two components: the one acting vertically downwards, and the other acting horizontally and contrary to the direction of working. The line of action being thus defined, it was inferred that the line of reaction upon the roof itself was of equal obliquity but of opposite direction. It was therefore averred that the principal planes of fracture (incipient or developed) in the roof, viewed from the mine below, must be projected over and towards the solid like the hade-lines of faults having their upthrows in the direction of working."*

In a subsequent paper on "The Great Planes of Strain in the Absolute Roof of Mines," he argued this proposition very fully, and arrived at the following conclusion:—

> "During its comparatively obscure transitional stages, mining subsidence constantly obeys (in the present) the same general rule as that known to have been obeyed (in the past) by natural subsidences, the ultimate stages of which are now manifest all over the globe.
>
> "This rule is the law of the normal fault—that the great (hade-) planes of strain in the normal case are always projected over and towards the solid (or unsubsided) strata—and mining subsidences with natural subsidences alike project their great planes of strain over and towards the solid."†

The Cantilever Idea.—The idea that the overlying strata may be considered as a huge cantilever whose load consists primarily of its own weight, has been ably discussed by Mr. H. W. G. Halbaum.‡ He argues that such a cantilever will be immeasurably stronger to resist compression than to resist tension; consequently, he infers that its neutral surface is very low indeed, probably not many feet above the roof-line. He uses this idea to support his contention as described above as the "oblique" theory; but incidentally he points out how the line of elementary strain supplied by the tensile component is inclined obliquely forward from the neutral surface, whereas the line of strain supplied by the compressive component is inclined backwards from the coal-face towards the neutral surface, thus explaining a fact which is well known to mining engineers, but of which the scientific explanation, as far as I know, had never previously been given, namely, that whilst the induced fractures in the "nether roof" are observed in the workings to incline backwards over the goaf, the ultimate line of break to the surface is inclined forward over the coal-face. Careful observations of the inclination of fractures in the nether roof under different conditions of dip and in strata of varying hardness might, if taken in relation with observations of the other factors which effect subsidence, be of use in helping to solve not only some of the problems of subsidence, but would also increase our knowledge of the action of the roof and its effects on the safety of working and the maintenance of roadways.

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* *Trans. Inst. M.E.*, 1905-1906, vol. xxx., page 175.

† *Ibid.*, page 198.

‡ *Loc. cit.*

V.—INFLUENCE OF FAULTS AND OF THE STRUCTURE AND CHARACTER OF THE OVERLYING ROCKS ON SUBSIDENCE.

Faults.—Fault-planes are planes of weakness in the strata. If the forces acting in the overlying rocks owing to mining operations tend to produce a plane of fracture in the neighbourhood of a plane of weakness, due to a fault, it is natural to expect that a fracture will be formed along the plane of weakness. It may therefore be expected that unequal settlement is likely to take place along the lines where faults reach the surface.

Where coal is worked on the downthrow side of a fault, the "draw," as it is sometimes expressed, for the reasons stated above, extends to the fault-plane, and serious damage may be caused to the surface considerably in advance of what might normally be expected.

Mr. S. R. Kay, in his paper read before the Institution of Civil Engineers, gives an example where "the working of the coal on the lower side of the fault at a depth of 350 yards (though only 3 feet in thickness) induced subsidence which extended to the line at which the fault was found at the surface, 200 yards horizontally from the point vertically over the nearest coal workings at the fault."*

When coal is worked on the upthrow side of a fault, the draw is usually reduced beyond the fault-plane, but a fracture is caused and increased subsidence takes place all along the fault-line. In either case the ground subsides on one side of the line, leaving the ground on the other side practically undisturbed; and if a building is standing partly on one side and partly on the other, very considerable damage will result.

Slips or "Nannies," which are probably incipient fault-planes, and usually run parallel with the nearest large fault and at about the same hade, are also planes of weakness, and may be expected to increase the draw if the coal is worked parallel with them, and the slips are inclined over the solid. On the other hand, if the slips are inclined backwards over the goaf, subsidence will take place more quickly and the "angle of draw" will be less.

"Cleat" or Cleavage.—When the working-face is parallel with the cleavage, particularly where the cleavage is well marked and the strata contain a large proportion of open-jointed sandstone, it may be expected that subsidence will be greater and the draw less than when the face is advancing "end on."

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* *Minutes of Procs. Inst. C.E.*, 1898-1899, vol. cxxxv., pages 115-116.

Character of Strata.—If Mr. Dickinson was correct in stating that hard rocks naturally break at a steeper angle than shales or softer rocks, it may be expected that the amount of draw will be less where the overlying strata include a preponderance of sandstone or similar rock. On the other hand, where the " nether-roof " consists of a bending rock the subsidence is slower and the " pull " is greater. Prof. George Knox writes:—

> " As the angle of pull under normal circumstances might be expected to approximate to the angle of repose of any particular series of rocks, the softer the beds the greater the angle of pull that should result. In mining this is not usually the case where the overlying strata consist of very thick hard layers of sandstone: the angle of pull is invariably larger than where the strata are soft." *

In comparatively shallow seams where the overlying strata are comparatively strong, and the " nether " roof will carry the weight for a considerable distance, but then breaks off, the breaks which occur at the same time as the " weights " at the coal-face may find their way through to the surface and cause unequal settlement; but this is not likely to occur at depths over 300 feet.

Unconformability.—If any of the strata lie unconformably on each other, a new factor is introduced; but it is difficult to say what effect this will have on the relation of draw to subsidence.

Old Workings.—The presence and condition of old workings in the overlying strata may have a most important bearing on the manner in which subsidence will take place, and often will account for unexpected results. The strata above the seams which have been previously worked may have settled to a position of rest, but will be more easily disturbed by subsequent workings than they were in their previous unbroken condition. It is usually found that the amount of subsidence in such cases is greater than would have resulted from the working of a seam of similar thickness in virgin ground. The term " supplementary subsidence " has been given to this extra amount. Where the whole of the coal has not been extracted in the upper seams, the supplementary subsidence may be very considerable; this is due to the pillars, which are already more or less crushed, being unable to support the additional weight which is thrown upon them. The draw from a lower seam will often " pull over " and extend to the fracture caused by the perimeter of the workings in upper seams in the same way as it does with faults. For this reason if too small a pillar has been left in an upper seam to support surface property, even when a far larger pillar than would otherwise have been necessary has been left in a lower seam, serious damage has been caused.

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* *Congrès Geologique Internationale*, 1913, vol. xii., page 804.

Surface Sub-soil.—The structure and character of the strata near the surface are very important factors. Where the sub-soil is of a yielding or plastic nature, the subsidence is likely to be more gradual and uniform, but it is generally accepted that a greater allowance should be made for draw, on the assumption that the angle of repose of the softer strata is greater. Where hard rocks, and particularly limestone, which is full of fissures, form the immediate surface, uneven settlement may be experienced even in advance of the coal-face.*

The Contour of the Surface is an important factor: buildings on steep slopes are liable to more serious damage than those built on level ground.

Water.—The presence of water in the surface beds may also be an important factor. It has often been found that serious damage may be caused to buildings by draining water from the supporting strata—for example, when laying sewers; in the same way, if water is drained off through fractures into the mine, or is removed by pumping when sinking, damage may result; but usually this is only the case with shallow mines. In deeper mines, if the water in the surface strata is not removed, it has not been found necessary to leave pillars larger than would otherwise be required, even where the works to be supported rest on quicksand or water-bearing gravel.

VI.—TIME FACTOR IN SUBSIDENCE.

The rate of advance of the working-face has an important bearing on the question. If the rate is rapid, fresh planes of incipient fracture are continually being formed in front of the advancing face, but sufficient time is not allowed for actual fracture to take place; consequently, the superincumbent rocks will tend to bend without breaking, and the subsidence will be more gradual and uniform, but the amount of draw will probably be greater. In case of stoppage for holidays or strikes, the interval may give sufficient time for an incipient fracture to develop.

The length of time which must elapse before complete settlement has taken place depends on many of the factors already mentioned; it is a point of considerable importance, especially with regard to the maintenance and repair of damaged buildings, and is one on which much difference of opinion has been expressed.

It is now generally accepted that less damage will usually be caused by working out the whole of the coal as quickly as possible than by leaving pillars: an insufficient pillar is undoubtedly worse than no pillar at all. If pillars have to be left, they should be of adequate size, taking all the various

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It is now generally accepted that less damage will usually be caused by working out the whole of the coal as quickly as possible than by leaving pillars: an insufficient pillar is undoubtedly worse than no pillar at all. If pillars have to be left, they should be of adequate size, taking all the various factors into consideration, and they must be left in the right place. The effect of leaving pillars in relation to the probable working of deeper seams at a later date is an aspect of the subject that requires careful consideration. With increasing depths the amount of draw is increased, and particularly with thinner seams; where the support afforded by the packing is relatively great, the angle of draw will also be increased, so that with such seams at great depths the amount of draw may be very considerable, and very large pillars would be required.

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* W. Hay, *Trans. Inst. M.E.*, 1908 1909, vol xxxvi., page 427.

VII.—SUGGESTIONS FOR FURTHER INVESTIGATIONS.

Prof. G. Knox, in his paper read before the International Geological Congress in 1913,* writes as follows:—

"There are several points which may be considered sufficiently well established to form a basis for further investigations, *e.g.*—

"(*a*) That surface subsidence invariably extends over a greater area than that excavated.

"(*b*) That the angle of pull is determined by the ratio between the excavated and subsided areas.

"(*c*) That this ratio is determined by a large number of factors, among which may be included the following:—

"1. The amount *and character* of permanent support left in the mined area.

"2. The thickness of the seam (etc.) worked.

"3. The depth of working from the surface.

"4. The method of working adopted.

"5. The direction of working in relation to the jointing *and dip* of the strata.

"6. The rate at which workings advance.

"7. The nature of the strata overlying the workings *and supporting the surface.*

"*7A. The presence of old workings and their condition.*

"8. The presence of faults, fissures, etc., in the strata.

"9. The permeability of the overlying rocks.

"10. The dip of the strata.

"11. The surface contour.

"12. The potential compressive forces existing in the strata containing the workings."*

Prof. Knox discusses each of the factors given, with a view to showing how the varied results noted by observers in different mining districts may be accounted for.

In colliery districts where several seams have already been worked, it is almost impossible to make any accurate deductions, however carefully observations may be taken; but I would suggest that in opening out new collieries it would be an excellent policy to have careful levels taken periodically of specially-laid-out bench-marks both in front and at each side of the working-faces. The variation in levels of these points with regard to the position of the working-faces at various dates would give sufficient information to ascertain the angle of draw in each direction. Once the angle is definitely established for the particular seam worked, this knowledge would enable those in charge to estimate with a fair degree of accuracy the size of the pillar required to support any particular surface works if it should be deemed desirable to leave support.

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* *Congrès Geologique Internationale,* 1913, vol. xii., page 798. I have taken the liberty of adding the words in italics.—W.D.L.

A word of caution may be necessary here: the following question requires an answer:—Will the angle of draw obtained in this way, while the workings are advancing, be sufficient without allowing a margin of safety to cover any further disturbance of the strata that will result when working is permanently stopped? Continued observation for several years after the coal has been worked under given points would furnish information as to the time taken for complete settlement of the surface, a point which is of great importance to the surface owner, and on which there is considerable divergence of opinion.

The amount of reliable data which has hitherto been published is comparatively small. If members would communicate the information they have or may obtain, together with as complete a statement of the factors involved as enumerated by Prof. Knox, it would be of inestimable advantage, as it is only by the consideration of the data of a large and varied number of instances of subsidence that our knowledge of the subject will be increased. Some members may be jealous of imparting to others knowledge of this sort which they have been put to some trouble to collect; but I may remind them that one of the principal objects for which The Institution of Mining Engineers was founded was the advancement of the science of mining by the exchange and discussion of information.

VIII.—AN OBSERVATION OF SUBSIDENCE.

I am indebted to Mr. William Kirkby for the following data of observations recently made, and for allowing them to be published. Fig. 2 (Plate II.) is a plan of the workings; Fig. 3 is a longitudinal section on the line *AB*; and Fig. 4 (Plate III.) is a cross-section on the line *CD*. Taking the factors in the order suggested by Prof. Knox, the following information is available:—

(1) The amount of permanent support left in the mined area: Part of the mined area for a width of 4 chains (264 feet) and a length of 825 feet, being the length from *A* to *B*, was specially packed as tightly as possible with hard rock in order to afford extra support to certain surface works, and also with the idea of rendering the surface subsidence gradual and uniform. The remainder of the mined area was packed in the usual way, as described under (4).

(2) The thickness of the seam worked was 3 feet 10 inches of clear coal, and the holing was done in the coal; the total height of the working-face was thus 3 feet 10 inches, the same as the thickness of the seam.

(3) The depth of the workings from the surface was about 1,066 feet, varying slightly according to the dip of the seam and the contour of the surface.

(4) The method of working was advancing longwall, with gates 99 feet apart; gate-packs 12 feet wide were put on with the bind from the first ripping, which was usually 2½ feet thick, and was carried 8 feet wide at the bottom and 6 feet wide at the top. The cross-gates were 264 feet apart; the first ripping in the cross-gates was 3 feet thick, 10 feet wide at the bottom, and 8 feet wide at the top; the cross-gate packs were usually 18 feet wide. Middle packs were put on as far as possible 6 feet square, with wastes 18 feet wide; they were composed of strong rock from the second ripping. Very little second ripping was required in the ordinary gates, but a second ripping of 2½ feet was required in the main gates and in the cross-gates. The gate-end packs were made up to within 5 feet of the face, and the middle packs were kept up to about the same distance. The method of work was to break in at the gate end for 12 feet and take a " lift " or " buttock " of 12 feet with the tub-road close to the face timber. The method of timbering was as shown in Fig. 5 (Plate III.). No chocks were used, but wooden packs formed of old timber and filled in with dirt were used to set out new gates off the cross-gates. All timber was withdrawn as the face advanced, one row of timber being left 2 feet from the face when the side was drawn out until the next buttock came across. In the area specially packed the gate-packs were put on with bind from the first ripping in the usual way, and the whole of the rest of the bank was practically packed solid with rock, much of which was in large pieces, the front wall being made up to 2 feet from the face as each bank was drawn out. The gates, which had to be carried in the specially-packed area, were stowed up with rock as soon as they were cut off by the next cross-gate.

(5) The general direction of the working-face was at right-angles to the jointing of the strata and parallel to the line of dip.

(6) The rate of advance varied from 150 to 270 feet per year as the faces were gradually extended.

(7) The roof consisted of 2½ feet of strong blue bind, above which was a thick stratum of strong rock about 45 feet thick. The floor consisted of hard spavin about 5 feet thick.

(8) There were no faults, fissures, etc., noticeable in the overlying strata, and the coal was free from any marked slips or "nannies"; the cleavage was well marked both in the coal and in the rock.

(9) The overlying strata consisted of ordinary coal-measures, with several beds of strong rock and bind, which would probably settle gradually without breaking and thus prevent any surface water from penetrating far into the disturbed ground. The

TABLE I.—LEVELS TAKEN ON LONGITUDINAL-SECTION LINE *A*—*B* (FIG. 3, PLATE II.).

Peg No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	000′	50′	100′ *A*	150′	200′	250′	300′	350′	400′ line of *C*—*D* crossing.	450′	500′	550′	600′	650′	700′	750′	800′	850′	900′	950′ *B*	1,000′	1,050′	1,100′
June, 1912	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63
June, 1914	165·63	163·63	163·63	163·53	163·63	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,
Dec., 1914	163·63	163·63	163·63	163·38	163·34	163·43	163·52	163·63	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,
June, 1915	163·63	163·63	163·60	163·21	163·06	163·07	163·18	163·27	163·33	163·49	163·63	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,
Dec., 1915	163·63	163·63	163·42	163·05	162·90	162·88	162·93	163·01	163·06	163·11	163·23	163·32	163·46	163·63	,,	,,	,,	,,	,,	,,	,,	,,	,,
June, 1916	163·63	163·63	163·34	162·91	162·73	162·59	162·57	162·69	162·78	162·83	162·91	163·00	163·13	163·31	163·44	163·63	,,	,,	,,	,,	,,	,,	,,
Dec., 1916	163·63	163·63	163·16	162·71	162·51	162·43	162·40	162·43	162·47	162·49	162·55	162·61	162·75	162·90	163·05	163·16	163·30	163·45	163·63	,,	,,	,,	,,
June, 1917	163·63	163·59	163·13	162·57	162·34	162·25	162·16	162·16	162·21	162·21	162·26	162·33	162·38	162·51	162·61	162·71	162·84	163·05	163·25	163·43	163·53	163·63	,,
Dec., 1917	163·63	163·51	163·00	162·53	162·32	162·13	161·97	161·97	161·98	162·01	162·05	162·10	162·16	162·21	162·33	162·41	162·55	162·75	162·97	163·23	163·43	163·59	163·63
June, 1918	163·63	163·51	163·00	162·53	162·32	162·13	161·97	161·97	161·98	161·93	161·90	161·90	161·88	161·92	162·00	162·18	162·38	162·55	162·76	163·00	163·23	163·51	163·63
Subsidence	0·00	0·12	0·63	1·10	1·31	1·50	1·66	1·66	1·65	1·70	1·73	1·73	1·75	1·71	1·63	1·45	1·25	1·08	0·87	0·63	0·40	0·12	0·00

TABLE II.—LEVELS TAKEN ON CROSS-SECTION LINE *C*—*D* (FIG. 4, PLATE III.).

Peg No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	000′	50′	100′ *C*	150′	200′	250′	300′	350′	400′ *A*—*B* crossing.	450′	500′	550′	600′	650′	700′	750′	800′ *D*
June, 1912	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63	163·63
June, 1915	163·63	163·63	163·63	163·59	163·43	163·38	163·36	163·38	163·33	163·33	163·33	163·31	163·31	163·30	163·30	163·29	163·29
Dec., 1915	163·63	163·63	163·60	163·31	163·22	163·13	163·11	163·10	163·06	163·05	163·03	163·00	162·98	162·97	162·95	162·93	162·90
June, 1916	163·63	163·63	163·32	163·03	162·90	162·80	162·78	162·77	162·78	162·68	162·63	162·56	162·50	162·43	162·41	162·35	162·35
Dec. 1916	163·63	163·63	163·13	162·73	162·55	162·43	162·43	162·47	162·47	162·36	162·27	162·20	162·12	162·05	162·03	161·99	162·00
June, 1917	163·63	163·59	162·88	162·36	162·17	162·09	162·09	162·13	162·21	162·05	161·97	161·88	161·80	161·76	161·73	161·66	161·60
Dec., 1917	163·63	163·43	162·68	162·23	161·92	161·85	161·88	161·93	161·98	161·88	161·77	161·67	161·59	161·52	161·47	161·42	161·34
Subsidence	0·00	0·20	0·95	1·40	1·71	1·78	1·75	1·70	1·65	1·75	1·86	1·96	2·04	2·11	2·16	2·21	2·29

surface sub-soil consists of strong clay about 8 feet in thickness, underlain by a stratum of blue bind about 50 feet thick.

(10) The dip of the strata is uniform, being 1 in 37 to the north-east.

(11) The surface contour has no noticeable features. The pegs on line *AB* and on line *CD* were set to a dead level at 50 feet intervals before subsidence commenced.

(12) The measures are very regular, and form a part of the Yorkshire Coalfield; the nearest large fault is half a mile to the north; it crosses the field in an east-and-west direction, and has a downthrow of 90 yards to the east.

Tables I. and II. give particulars of the levellings from which sections *AB* and *CD* have been drawn.

IX.—CONCLUSIONS.

The nature of the surface works was very favourable to the taking of accurate observations, particularly along the line *AB* (Fig. 3, Plate II.), and allowed the amount, and particularly the amplitude, of the subsidence at any particular time with regard to the position of the working-face to be ascertained with greater accuracy than would otherwise have been the case.

Amount and Time of Subsidence.—The effect of the special packing is very noticeable. The total amount of the subsidence in the centre of the specially-packed area was practically 20 inches, whereas at the point marked *D*, where the workings were well extended, and with the ordinary method of packing, the settlement amounted to 27½ inches.

The settlement of the surface over the specially-packed area amounted to 43·4 per cent. of the thickness of the seam, and the maximum subsidence observed above the ordinary method of working was 58·7 per cent.

The amount of settlement at various dates at the point of intersection of the line of section is as follows, the coal having been worked vertically under this point in February, 1915:—

Date.	Inches.	Total.
1915.		
July 24th	3	3
1916.		
January 18th	3	6
April 28th	3	9
May 27th	1	10
September 14th	1	11
October 13th	1	12
1917.		
January 11th	3	15
March 20th	2	17
July 12th	1	18
August 9th	1	19
November 5th	1	20

No further settlement has taken place since November, 1917, up to February, 1919.

From the foregoing, it will be observed that the amount of subsidence five months after the coal had been worked underneath was 3 inches. It continued at the rate of half-an-inch a month for six months, then increased to an inch a month for four months. During the summer months it decreased, being at the rate of a quarter-of-an-inch a month for four months, increasing to an inch a month for six months; it decreased again during the summer to the rate of a quarter-of-an-inch a month for four months, then increased to an inch in one month, and ceased after the end of a further three months, during which the rate was a third-of-an-inch per month. The total time from the date the coal was worked until complete settlement had taken place was 34 months.

TABLE III. Showing the Amount and Angle of Draw in front of an Advancing Face towards *B* (Fig. 3, Plate II.). Seam, 3 Feet 10 Inches Thick; Depth, 1,062 Feet; Inclination of Seam, rising 1 in 640 in General Line of Section towards *B*.

Lines showing surface level on section *AB* (Fig. 3, Plate II.).		1	2	3	4	5	6	7	8	9
Date when work commenced: September, 1913.	—	June, 1914	Dec., 1914	June, 1915	Dec., 1915	June, 1916	Dec., 1916	June, 1917	Dec., 1917	June, 1918
Time from commencing excavation.	Months	9	15	21	27	33	39	45	51	57
Width of excavation on line of section *AB*.	Feet	128	194	325	477	557	666	823	--	—
Rate of advance per month (average over previous six months).	Feet	—	11	22	25½	14	18	26	—	—
Amount of subsidence vertically over face.	Inches	—	1	2	2½	3	4½	3	5*	7½*
Greatest amount of subsidence at date.	Inches	1·2	3·4	6·8	9·0	12·7	14·8	17·6	19·8	21·0
Distance of greatest amount of subsidence behind face.	Feet	102	118	199	350	381	491	597	549†	347†
Amount of draw on line of section at right-angles to line of face.	Fect	—	20	30	40	60	84	95	109	119
Angle of draw from vertical.	Degrees	—	1° 9′	1° 37′	2° 9′	3° 14′	4° 31′	5° 6′	—	--
Amount of draw at right-angles to boundary pillar.	Feet	—	—	—	—	—	—	-	102	111½
Angle of draw at right-angles to boundary pillar.	Degrees	—	—	—	—	—	—	—	5° 29′	6° 0′
Amount of draw in advance of normal at right-angles to pillar.	Feet	—	—	—	—	—	—	—	94	103½
Angle of draw in advance of normal at right-angles to pillar.	Degrees	—	---	—	—	—	—	—	5° 3′	5° 34′

* Total over pillar edge. † Face stopped.

Amplitude of Subsidence.—Table III., which is compiled from section *AB* (Fig. 3, Plate II.), shows that the first subsidence of the surface was not noticeable until 9 months after the excavation was commenced. At that time 128 feet of coal had been removed along the line of section from point *A*. The first subsidence showed at its greatest at Peg No. 4, the amount being 1·2 inches, running out in each direction, but it did not reach the point *A* by some 6 feet; towards the point *B* it was about 55 feet behind the advancing face. There was, therefore, at that time no draw in either direction. Six months later, or 15 months from the commencement of working, the width of the excavation being then 194 feet, the draw showed itself 20 feet in front of the working-face, the angle of draw being 1 degree 9 minutes. The greatest amount of subsidence showing at that time was 3·4 inches at a distance of about 118 feet back from the face.

Table III. shows how the draw in front of the face continued to swing forward as the excavated area extended. With 325 feet of excavated area, it was 30 feet; with 477 feet, it was 40 feet; with 557 feet, it was 60 feet; with 666 feet, it was 84 feet; and with 823 feet, it was 95 feet. The face had then reached the opposite pillar or boundary, and the line of draw made an angle of 4 degrees 31 minutes with the vertical to the coal-face.

A point which is worth noticing is that after the face stopped, the draw continued to exend slightly from 95 feet to 109 feet in the first six months, and only reached its fullest extent of 119 feet twelve months after the face had ceased to advance. Presumably this would be due to the crushing of the edge of the coal-pillar, and this observation gives an answer, as far as this instance goes, to the question previously raised, namely, that the angle of draw shown in front of the advancing face is not sufficient to allow for an increased amount of draw after the face had ceased work, without adding a margin for safety in setting out a pillar for support. Whether or not the amount of draw would have continued to increase if the excavation had been continued, the data gives no definite guide, but it seems probable that it had not quite reached a maximum. The width of the excavation on the line of section was then 823 feet, or, say, three-quarters of the depth; but at the same time it should be noticed that the excavation had only extended in an easterly direction from the line of section to 320 feet, or less than a third of the depth. The full settlement had barely been reached at Peg No. 5 at a point 750 feet behind the face, and the maximum subsidence had not been reached at any point.

In considering the extension of the draw after the working had ceased, it should be pointed out that the boundary pillar was not parallel to the advancing face, or at right-angles to the line of section. The maximum amount of draw at right-angles to the pillar at the point *B* was 111 feet, making an angle of 6 degrees with the vertical. On the line at right-angles with the pillar the inclination of the seam towards the pillar was 1 in 130; the amount of draw due to the normal of the seam would be 8 feet, making an angle of 0 degrees 26 minutes with the vertical, leaving the amount of draw in advance of the normal 103½ feet and the angle of draw in advance of the normal 5 degrees 34 minutes.

TABLE IV.—SHOWING THE AMOUNT AND ANGLE OF DRAW OVER A PILLAR BEHIND AN ADVANCING FACE AT THE POINT *A* (Fig. 3, Plate II.). SEAM, 3 FEET 10 INCHES THICK; DEPTH, 1,066 FEET; INCLINATION OF SEAM TOWARDS *A*, 1 IN 47 AT RIGHT-ANGLES TO THE PILLAR.

Lines showing surface level on section *AB* (Fig. 3, Plate II.) at date.		1	2	3	4	5	6	7	8
Date when work commenced: September, 1913.	—	June, 1914	Dec., 1914	June, 1915	Dec., 1915	June, 1916	Dec., 1916	June, 1917	Dec., 1917
Time from commencing excavation.	Months	9	15	21	27	33	39	45	51
Width of excavation on line of section.	Feet	128	194	325	477	557	666	823	823
Amount of subsidence at edge of pillar.	Inches	—	0·7	2·6	4·6	6·0	8·1	9·2	10·3
Greatest amount of subsidence at date.	Inches	—	3·4	6·8	9·0	12·7	14·8	17·6	19·9
Distance of greatest amount of subsidence from *A*.	Feet	—	76	76	126	176	176	176	176
Amount of draw on line of section.	Feet	—	8	27	45	50	63	78	90
Angle of draw from vertical.	Degrees	—	0°26′	1°27′	2°25′	2°41′	3°23′	4°11′	4°50′
Amount of draw corrected for right-angles to pillar.	Feet	—	7½	25½	42¾	47½	60	74	85½
Angle of draw corrected for right-angles to pillar.	Degrees	--	0°24′	1°22′	2°18′	2°33′	3°13′	3°58′	4°35′
Amount of draw in advance of normal to seam.	Feet	—	—	2½	19¾	24½	47	51	62½
Angle of draw in advance of normal.	Degrees	—	—	0°08′	1°04′	1°19′	1°59′	2°44′	3°21′

Table IV., which is also compiled from section *AB* (Fig 3, Plate II.), shows that the first draw over the edge of the pillar behind the advancing face at the point *A* appeared 15 months after the excavation commenced, at which time the width of the excavation was 194 feet; the amount of the subsidence on the edge of the pillar was then only 0·7 inch; the amount of draw over the pillar continued to increase as the workings advanced away from the pillar, and reached a maximum of 90 feet 51 months after working commenced. The maximum angle of draw on the line of section was 4 degrees 50 minutes; corrected for right-angles to the pillar, the amount of draw was 85½ feet and the angle 4 degrees 35 minutes. The dip of the seam at right-angles to the pillar was 1 in 47 towards the pillar. The amount of draw due to the normal of the seam would therefore be 23 feet, making an angle of 1 degree 14 minutes with the vertical, leaving the amount of draw in advance of the normal as 62½ feet and the angle of draw in advance of the normal as 3 degrees 21 minutes.

TABLE V.—SHOWING THE AMOUNT AND ANGLE OF DRAW OVER A PILLAR ON THE SIDE OF AN ADVANCING FACE AT THE POINT *C* (Fig. 4, Plate III.). SEAM, 3 FEET 10 INCHES THICK; DEPTH, 1,071 FEET; INCLINATION OF SEAM TOWARDS *C*, 1 IN 47 AT RIGHT-ANGLES TO THE PILLAR.

Lines showing surface level on section *CD* (Fig. 4, Plate III.) at date.		1	2	3	4	5	6
Date at which working-face passed the point *C*: August, 1915.	—	June, 1915	Dec., 1915	June, 1916	Dec., 1916	June. 1917	Dec., 1917
Time before face passed point *C*.	Months	2	—	—	—	—	–
Time after face passed point *C*.	Months	—	4	10	16	22	28
Width of excavation at right-angles to *CD*.	Feet	300	800	over 800			
Distance along pillar to which face had advanced beyond *C*.	Feet	40	70	150	240	470	470
Amount of subsidence vertically over edge of pillar.	Inches	—	0·9	1·9	7	10	12½
Amount of draw on line of section *CD*.	Feet	—	14	40	55	65	98
Angle of draw on line of section *CD*.	Degrees	—	0° 45′	2° 08′	2° 56′	3° 28′	5° 18
Amount of draw corrected for right-angles to pillar.	Feet	—	10	29	41	48½	73
Angle of draw corrected for right-angles to pillar.	Degrees	—	0° 32′	1° 33′	2° 12′	2° 43′	3° 54′
Amount of draw in advance of normal to seam.	Feet	—	—	6	18	25½	50
Angle of draw in advance of normal to seam.	Degrees	—	—	—	0° 39′	1° 10	2° 21

Table V. shows the amount and angle of draw over a pillar at the point *C* on the dip side of an advancing face, and is compiled from the section *CD*. It should be noticed that the line of the pillar edge was not at right-angles with the face, but made an angle of about 48 degrees with it. No sign of draw was shown before the face passed the point *C*, but it showed to the extent of 0·9 inch when the face had passed the point 4 months and had advanced 70 feet beyond it. At that time the draw extended over the pillar 14 feet on the line of section, which would be equal to 10 feet at right-angles to the pillar. The amount of settlement at the point *C* continued to increase at a fairly regular rate until it attained its maximum of 12½ inches, 28 months after the face had passed; the amount of draw extended during the same time till it reached its final amount of about 98 feet on the line of section, or 73 feet at right-angles to the pillar. The dip of the seam at right-angles to the pillar was 1 in 47; the law of the normal would account for a pull over of 23 feet, leaving 50 feet of draw in excess of the normal at right-angles to the pillar. The final line of draw thus made an angle of 2 degrees 21 minutes in advance of a line normal to the seam. It should, however, be pointed out that the amount of draw in this case has probably been overstated, as shown by the flattening of line 6 towards Peg No. 1, section *CD*; the facilities for accurate observation between the pegs were not available in this case as they were along the line *AB*.

As the seam lay comparatively horizontal, the amount of draw due to the normal to the seam is comparatively slight, and in most cases would probably be ignored. The results given, however, show that there is probably a considerable difference in the amount of draw over a pillar according to the direction in which the pillar lies with regard to the mined area; thus at *B*, with the pillar in front of the working-face, the draw was greatest, namely, 5 degrees 34 minutes in advance of the normal; it was least at *C* over a pillar on the side of the advancing face, namely, 2 degrees 21 minutes in advance of the normal; and at the point *A* over a pillar behind the advancing face it was 3 degrees 21 minutes.

Mr. Percy Greaves (Wakefield) wrote: I disagree with Mr. Lloyd that the subsidence is greater in the case of shallow seams than in the case of deeper ones. My experience is that the greater the depth the more certain and the greater the subsidence, and I think that this view is logical. Take the simple example of a railway-bridge: provided that the span is long enough, no matter what the strength of the bridge may be it will ultimately break. On applying the same reasoning underground, one arrives at the same conclusion. In the case of deep mines after working subsidence takes place, and all packing is crushed very much tighter than in shallow seams.

A great deal of coal has been left to support buildings and railway works which ought never to have been left, and one of the best examples I can give is that of a large electricity works in this neighbourhood. The Corporation had either to buy a pillar of coal, valued at £18,000, or allow a seam of coal 3½ feet in thickness to be worked underneath it. On my advice they took the risk, and the coal was worked. The whole work subsided to a depth of 2 feet 5 inches, but not more than £500 worth of damage was done, part of which was to sewage tanks, which are obviously very weak structures. I may mention in connexion with this that a very tall chimney became considerably out of plumb, and then actually came back to a nearly perpendicular position. A high-speed engine-set ran five-eighths of an inch out of level for some months. It was brought into level again by means of wedges; ultimately these wedges were taken out, and the engine-set resumed its normal position. No stoppage of any kind took place during the whole time that mining was going on, and not even a steam-joint was broken.

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Table V.—Showing the Amount and Angle of Draw over a Pillar on the side of an Advancing Face at the Point *C* (Fig. 4, Plate III.). Seam, 3 feet 10 inches Thick; Depth, 1,071 feet; Inclination of Seam towards *C*, 1 in 47 at Right-angles to the Pillar.

Lines showing surface level on section *CD* (Fig. 4, Plate III.) at date.		1	2	3	4	5	6
Date at which working-face passed the point *C*: August, 1915.	—	June, 1915	Dec., 1915	June, 1916	Dec., 1916	June. 1917	Dec., 1917
Time before face passed point *C*.	Months	2	—	—	—	—	—
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Width of excavation at right-angles to *CD*.	Feet	300	800	over 800			
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Amount of draw in advance of normal to seam.	Feet	—	—	6	18	25½	50
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I have known cases where subsidence has amounted to 75 per cent. of the coal extracted, and extremely little damage having even then been done. Perhaps I can give no better example than one where 3½ feet of coal was removed from underneath a large house in the occupation of a well-known mining engineer. He did not, I think, know about it until I told him, even though the house itself subsided 2 feet.

Mr. R. W. DRON (Glasgow) wrote: It is difficult to carry out a series of observations extending over a period of several years and secure at the same time all the conditions which comply with the scientific requirements. This accounts probably for the fact that not many records of such observations have been published. In response to Mr. Lloyd's request, the following notes are given, although they are imperfect in several respects. The levels referred to were not taken with a view to publication, but they may be of value as a contribution to the discussion of this subject.

In 1903 to 1905 I had occasion to take levels with the object of ascertaining the amount of subsidence affecting a dwelling-house. About 20 years before the erection of this house three seams had been worked, having an aggregate thickness of about 15 feet, and lying between 250 and 350 feet from the surface. The overlying strata had consolidated, and no fear was entertained of further subsidence due to the working of these seams. The seam which was being worked in 1903 was 33 inches thick at a depth of 500 feet, and lay at an inclination of 1 in 12. The system of working was longwall by coal-cutters holing in the seam, the gate-roads being 45 feet from centre to centre. The pack-walls occupied a space of about 11 feet on either side of the gate-roads, leaving an unoccupied space of about 15 feet in the gob. The working-face had approached the house before the first observation was taken, and there must have been a slight subsidence prior to that. Judging from experience of similar cases, I estimate this at about 3 inches. The subsequent observations were as follows:—

Observations.	Feet.	Average subsidence per day. Feet.
Subsidence between 7/7/03 and 17/9/03	=0·23	0·0032
,, ,, 17/9/03 ,, 11/1/04	=0·63	0·0054
,, ,, 11/1/04 ,, 11/4/04	=0·39	0·0042
,, ,, 11/4/04 ,, 28/6/04	=0·23	0·0030
,, ,, 28/6/04 ,, 11/11/05	=0·43	0·0008
,, prior to July 7th, 1903 (estimated)	0·25	
Total subsidence ...	2·16	

By December, 1903, the working-face had advanced to a line 330 feet beyond the house and there stopped, having reached the boundary.

The subsidence of 26 inches, due to the working of a seam 33 inches thick, was in this case over 78 per cent. of the thickness. The amount appears to be abnormal, and may be due to the previous workings in the upper seams. The estimate of 3 inches prior to July, 1903, is, of course, an element of uncertainty in the calculation.

During the same period levels were taken along the roadway in front of the house. These levels indicated that at a point vertically above the line where the working-face stopped in December, 1903, the amount of subsidence which occurred during the period from July 7th, 1903, to April 11th, 1904, was 1·2 feet, being practically the same as shown on the foregoing table for subsidence at the house for the same period. At the same time it was observed that the subsidence extended beyond the face-line, gradually tapering out until it was zero at 420 feet beyond the face-line. Unfortunately, alterations in the road, together with other circumstances, prevented the continuance of these observations beyond April, 1904. I had an opportunity in another case of taking levels on the surface overlying an area from which a seam was being worked on the hydraulic system. Unfortunately, after 1914 it was found impossible to continue these observations, but the results obtained up to that date were of some interest. The seam was 4 feet thick, 240 feet deep, and lay at an inclination of 1 in 10. The area worked measured approximately 500 feet by 500 feet. The stowage was washer *débris*. There was no sign underground of any subsidence. The surface levels showed that the subsidence was in the form of a trough, the maximum observed subsidence being 12 inches in the centre of the area worked. The feature which struck me as most noticeable was that there was no observed subsidence along the outside edge of the area. It has frequently been contended that with close stowage the " draw " extends for a greater distance than is the case when the stowage is loose, but in this instance the opposite result was observed.

It seems to me that there is much confusion of thought in connexion with the word " draw." The term " angle of draw " is used by Mr. Lloyd, but no exact definition is given as to the meaning of the term. It would be an advantage in future discussions if an agreement could be arrived at either to cease using the word in scientific discussions or to define exactly what it means. It is quite right to discuss the angle beyond which, in given circumstances, it is probable that the subsidence will not extend so as to cause any appreciable damage. For instance, in the case above cited the limit of subsidence in the first instance extended to 420 feet beyond a face-line 500 feet deep, and in the second case the limit of subsidence was vertically above the face. In this

Mr. THOMAS BEACH (Hemsworth): Mr. Lloyd has undoubtedly had exceptional opportunities for taking his observations, in having a level surface and a fairly level seam. We should not forget, however, that the subsidence described is taking place over a specially-packed area. It might have been rather larger, and conditions might have been very different, if the area had not been specially packed.

The PRESIDENT (Mr. W. D. Lloyd): I have done my best to introduce the subject with the object of inviting other members to bring forward information in their possession, so that data can be collected which I am sure will be interesting and of great value. Most of the definite data which have been published date back to the end of last century. Since then the method of working has been altered, and for actual longwall working very few data have been published. Additional data are required, with, in each case, as much information as possible regarding the different factors. Perhaps Mr. Rhodes will some day give us definite information on the cases to which he has referred; Mr. Merivale has kindly promised to supply records when they are completed; I think Mr. Kirkby will also be able to give us further examples; and I hope other members will do the same. It is not necessary that each member should make a long contribution, but what we want is as accurate and full information as possible on particular cases. If members can have particulars ready to bring forward for further discussion of the paper at the July meeting, I am sure their contributions will be of great benefit to us all.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

Held in the Wood Memorial Hall, Newcastle-upon-Tyne,
April 12th, 1919.

Mr. JOHN SIMPSON, President, in the Chair.

COAL-CUTTING BY ELECTRICITY AND TIMBERING AT CANNOCK CHASE COLLIERY.

By W. P. CHEUNG, B.Sc.

Coal-cutting.—Cannock Chase Colliery was favourably placed in having at its disposal an installation of alternating-current plant* of sufficient capacity for coal-cutting.

There are five drawing pits within a radius of 2 miles, and eight seams are worked, varying in depth from 250 to 900 feet, in five of which coal-cutters have been introduced. Despite natural difficulties such as faults, unevenness of floor, and variable gradients, the installation of coal-cutters has been a decided success. After a trial of three types of cutter, the most used now is the Hopkinson chain-cutter, which undercuts to a depth of 5 feet with a cut of 4 inches.

The longwall method of working is used, the machine-face has a straight face of from 60 yards to 120 yards, and the holing is " end on." Taking a typical example of a machine stall of 100 yards in a 4½-foot seam, an advance of 180 yards was made in twelve months, with the assistance of an electric belt-conveyor.

The machine-face is generally cleared on the day-shift, so as to be ready for coal-cutting by the night-shift. The machinemen are paid at piecework rates. The delivery of coal in the conveyor-face is from one extremity of the face to the other, and, as the tubs are filled, the set is hauled away by main-and-tail rope, which is brought close to the face whilst in the machine-stall, without the conveyor. Where the height of the seam allows, and conveyors are not in use, advantage is taken of the dip of the seam, and the district is laid out so that the tubs are taken in at the higher end in sets of ten or more, and, as they are filled, gravitate to the end road 60 or 120 yards away, where they are picked up by the haulage. As many as twenty loaders are employed on these faces.

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* "Electrification of Cannock Chase Colliery." By S. F. Sopwith. *Trans. Inst. M.E.*, vol. xlv., page 350.

In the Bass Seam, which is liable to gob-fires, it has been found that there is less ground for anxiety on that account owing to the goaf being packed closely with incombustible dirt.

Economy in working has been marked, and without going into any details it may be stated that the results are eminently satisfactory, varying, of course, with the circumstances, but showing a saving all round. More round coal is now obtained, which is of importance to this colliery.

Finally, the advantages and, especially during war conditions and consequent shortage of labour, the output have been maintained in a manner which would have been quite impossible in any other way.

In 1913 the output from one coal-cutter was 1,138 tons, and this amount increased until in 1918 the output was 247,000 tons from thirty machines, which represents nearly 41 per cent. of the total output, and gives an average of 8,230 tons per machine. It may be mentioned that, owing to the number of pits and scattered nature of the workings, more machines are necessary than would be the case if the workings were more concentrated. The following comparative figures will be of interest:—

Year.	Output by machines. Tons.	Total output. Tons.	Total output by machines Per cent.
1913	1,158	613,537	0·19
1914	1,565	586,757	0·27
1915	38,938	680,338	5·72
1916	108,741	701,072	15·51
1917	176,202	677,980	25·99
1918	247,675	605,342	40·91

If all the coal produced by this colliery in the year 1918 had been worked by hand instead of by both methods, the output would have been 76,700 tons less.

When an electric installation is in a dangerous condition, it gives no warning to the sight or hearing, so that strict supervision by efficient men and the use of the best apparatus have been carefully observed. That this is the case is shown by the fact that no serious accidents have taken place, although the transmission voltage is 3,000, which is reduced to 600 volts for the coal-cutter.

Only one personal accident has taken place, owing to the carelessness of the man in charge in trying to tighten a coal-cutter chain while in motion. This was entirely against the rules, and he lost a finger in consequence.

The attitude of the men proves their confidence in the installation, for the machine stalls are eagerly sought after, and the old prejudice against electricity seems to have died out.

Timbering.—The economy in the use of timber is very marked, especially in the Bass and Shallow seams, which now require only 5-foot as against 7-foot timber in the hand-stalls. An opportunity has been given to try further economies in timbering, notably in the use of the economiser and S-F Metal props.*

The economizer is a cast-iron hollow cone 9 inches long, the wider end of which is fitted about 4 inches over the end of an ordinary tapered prop, thus leaving an empty space of 5 inches between the small end of the prop and the floor when set. When depression in the roof takes place, the prop is squeezed into the empty and narrower part of the tapered cylinder, or hollow section of the cone, until it reaches the floor. If something must go, the prop breaks where the edge of the cylinder cuts the wood. The prop can then be withdrawn, re-tapered, and fitted again into the economizer, and additional economizers can be placed in the original, like fitting flower-pots inside each other, in order to make up the required length, and these are again set. In this way a piece of timber can be used to a very short length by using even six or seven economizers. When the prop becomes too short for further use, it can be split and made into lids.

After twelve months' experience, this device shows a saving of 50 per cent. in timber, and, in addition, the men are not subjected to any delay for want of timber.

The S-F metal prop is a later design, in which the economizer is used, but there is the advantage of the height of the prop being adjustable, and a device for the easy withdrawal of the same, whereby very little timber is used.

The prop can be used in seams varying in height from 3 to 6 feet, and can also be used in hand-stalls.

The adoption of coal-cutting machinery has doubtless saved the situation during the extremely hard conditions imposed by the war, so that its introduction has been abundantly vindicated.

DISCUSSION OF MR. CHARLES J. FAIRBROTHER'S "RECORD OF GAS-PRESSURE FROM A BOREHOLE."†

Mr. **James Gibson** (Cleveland, Transvaal) wrote: There is little doubt that the gases expelled were the ordinary hydrocarbons, although no mention is made as to their composition. In South Africa it is, I believe, unusual to find gas occluded under such pressure, hence the record is an important one. I think the author might state whether this is the only occasion on which such a phenomenon has been noticed, and how long the pressure continued before it eased off.

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* *Iron and Coal Trades Review*, 1918, vol. ., page 491.

† *Trans. Inst. M. E.*, 1918-1919, vol. lvi., pages 6 and 126.

Mr. W. TAYLOR HESLOP (Natal) wrote: I obtained very clear proof, some years ago, at St. George's Colliery, Natal, of the transmission of gas through sandstones, as mentioned by Mr. J. B. Atkinson. In driving through a dolerite dyke the main place was in the lower seam and was driven into coal, and then in coal some 12 yards to the left. The return drive was in the upper seam, and some 8 yards in coal after passing through the dyke, until it reached a point immediately over the lower seam cross-drive. In both cases gas was encountered, but not in sufficient quantity to interfere with the work. As soon as the intervening bed of laminated sandstone was blasted through and a connexion made for ventilation, the places and the return-air course for some considerable distance became foul with gas, thus proving unmistakably that the sandstone was more porous to gas than either of the coal-seams.

Generally in Natal when a new coal area is tapped, either by a shaft or through a dyke, gas is given off more freely than is the case in Great Britain; but it " bleeds off " quickly after some time has elapsed, and there is less gas than is usual in Great Britain. Probably the reason for this is that the sandstone bed between the two seams acts as an effective conduit for the gas given off by the coal. For the same reason, at times I found it necessary to put up boreholes into the sandstone roof, when developing drives, in order to tap the gas and prevent the gas-pressure from breaking down the roof of from 4 to 6 feet of sandstone which underlies the upper seam. I also found that gas-pressure broke down the siliceous-shale roof of the upper seam when the seam was first broken into, but after development had proceeded some distance no further trouble occurred.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

Held at the Mining School, Stoke-on-Trent, February 17th, 1919.

Prof. Sir JOHN CADMAN, K.C.M.G., D.Sc., President, in the Chair.

RECENT DISCOVERIES IN PHYSICS.

Lecture by Sir OLIVER LODGE, D.Sc., LL.D., F.R.S.; Principal, Birmingham University.*

I have been very uncertain what to talk about. It was quite useless to talk about coal, or geology, or mining, because you know far more about those things than I do, and so I have concluded that it might be more interesting if I talk about some discoveries in science which have been made in the present century, for, during the early years of this century the progress in physics has been quite remarkable, and the electrical theory of matter has been born, so that nowadays we take quite a different view—not exactly a different view, but a much more expanded view—of the constitution of matter than we did, say, thirty years ago.

The structure of the atom has been worked out, although not by any means completely. The whole matter is still in the nascent stage, and much progress has still to be made, but a lot of steps have been taken, and some of them must be of interest to every educated person.

The fundamental property of matter is inertia—that which is commonly called "mass" and is measured by weight. It has been known from time immemorial, and in the old days no one ever thought of explaining it. It was taken as one of the fundamental properties of matter; and into the reason of it, or the mechanism of it, nobody attempted to penetrate. Of late, however, there have been discoveries made about this material inertia, or mass, which may, of course, be known to you more or less, but which, nevertheless, may be of interest.

The first law of motion is that a body left to itself continues to move uniformly in a straight line. In other words, matter requires force to start it or change its motion, but, once in motion, it would continue until it was stopped by force. That was a familiar definition of inertia—its persistence in its state, whatever it might be. The ordinary example given was that of a stone on the surface of ice, where you have very little friction; but the best example is not that, but the case of a train at steady speed, or a ship. When a ship is travelling at a definite speed across the Atlantic, no resultant force is acting upon it. The engines are propelling it, but all the force is occupied in overcoming the resistance of the water. The retarding force and the propelling force are equal and opposite; the resulting force is nil. The body moves by its own inertia. So it is in a train; so it is in a lift, or in a colliery shaft. As long as the motion is steady, we feel nothing of it; only at stopping or starting, when there is an acceleration of movement, do we feel it. We have a sense of acceleration; we know when the train is getting up speed, when the brakes are being applied, when the train is going round a curve; but if it is travelling in a straight line at a steady speed, we feel no motion beyond vibration. People do not generally realize that that is an example of the first law of motion—a body persisting in movement, because there is no force acting upon it.

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* Printed from the shorthand-writer's notes.

Here, in this room, we are all travelling at 19 miles a second with the earth in its orbit. We may be travelling much faster; I have reason to think we are travelling much faster than that through space, because, in addition to the earth travelling round the sun in its orbit at 19 miles a second, the sun itself is travelling at 12 miles a second, and the visible stellar system is believed by astronomers to be moving at a much greater pace through space. The stellar system to which we belong is like one of the nebulæ or clusters which are now found to be travelling at a prodigious pace—more like a 100 miles per second.

We do not know the pace at which we are travelling through space. Many attempts have been made to ascertain that speed: elaborate experiments have been made to attempt to measure the speed of the earth through the ether; but no result has been arrived at—not because it is not moving, but because there are compensating causes to prevent our detecting the motion. Still we know we are moving at a great pace, no matter what pace. Nineteen miles a second is fast enough—much faster than the speed of a cannon ball. We are moving by our own inertia, simply because there is nothing to stop us. It is inertia which keeps things going.

The remarkable thing is that an electric current was discovered by Faraday, a long time ago, to have a property of this kind also. An electric current requires force—electromotive force, of course—to start it, and it requires resistance, which is a variety of electromotive force, to stop it; but, once started, it continues until it is stopped. An ordinary current, started in, say, a curtain-ring, by moving a magnet into the ring or taking it out, subsides, decays, dies out, in a fraction of a second by reason of the resistance—though if there is plenty of magnetism in the circuit, it can be prolonged. The prolongation of a current, or the inertia of a current, depends upon its magnetic properties—upon the magnetism which it excites. And this is the kind of inertia which is explicable and reducible to something else. The inertia of an electric current can be explained magnetically. Consider the current along a wire. It is surrounded by a magnetic field, especially when there is an electro-magnet in the circuit. A little time is required therefore for the current to get up speed, and again a little time for it to stop.

Sir Oliver explained the point by means of curves, and said that time is of the essence of any start; time is also of the essence of any stoppage. If we try to stop a train or a cannon-ball suddenly, we have a collision and a smash; and if we try to stop a current with a lot of magnetism suddenly, we get a flash, familiar to everybody—the sign of electric inertia. Faraday called it the extra current; it is called by mathematicians "self-induction." That which is called self-induction is analogous to inertia; it is as if the electric current had inertia of its own.

Take a truck on a line of railway and push it. It takes time for the speed to get up; once started it goes easily. The two laws are similar, material and electrical; and the stoppage of the truck is, again, analogous to the stoppage of the current. Putting on the brake is like putting on resistance into the circuit. There is some resistance always, and if we do not propel a current in an ordinary circuit, it ceases very quickly.

But there has been a remarkable discovery dependent upon the utilization of very low temperatures. We know, of course, that of late years people have been able to get to temperatures immensely lower than used to be available. In Fahrenheit's time the lowest temperature was a mixture of ice and salt. Fahrenheit thought that was so low that he would never get lower, and he called it "zero." However, they soon got lower than that, in the case of solid carbon dioxide, and so on. With liquid air they got hundreds of degrees below freezing point. With liquid hydrogen they got 450 degrees below the Fahrenheit zero. With liquid helium they could get within 3 or 4 degrees of absolute zero. Absolute zero has been calculated with precision to be minus 490 degrees Fahrenheit below freezing-point, and we have got as far as 486 degrees, but it is not easy to do this. The man who has been most successful in doing it is Prof. Kamerlingh Onnes, of Leyden, in Holland. A good deal has been done in this country at the Royal Institution by Sir James Dewar and others, but Prof. Onnes has recently obtained liquid helium and immersed lead in it. It was already known that as they reduced a metal in temperature, it conducted electricity more and more easily. If only we could make an Atlantic cable and find a means of keeping it very, very cold—I suppose it is quite hopeless—telegraphy would become extraordinarily simplified, and it would be quite easy to telephone to America. The conductivity of copper, and of any other metal, increases so rapidly as the temperature goes down. but when we come to these excessively low temperatures the resistance disappears and the conductivity becomes, not absolutely perfect, but very nearly perfect.

The result he found was this. He took a ring of lead, like a curtain-ring—lead is not a particularly good conductor—and started a current in it by pulling a magnet half-way through. That current continued; it did not stop. It was a most amazing experiment, for whereas a current generally stops in a fraction of a second, this one went on for hours, and when he went next day to measure the current he found it still there. The current, once started, was still going on, and in four days it had only fallen to a third its value, so that in a fortnight there was still a trace of it left. That was a most curious, striking, and suggestive experiment. It showed that the resistance of metals depends upon their temperature; that is, the rapidity with which the atoms are quivering. And if the metal was cooled so that the atoms were practically frozen together, instead of jostling higgledy-piggledy, they passed the current on from one to the other with perfect ease, continuing the current for days; and, perhaps, if they could get to absolute zero, for always.

There are reasons to believe that this is so inside the atoms. There are reasons to believe that there are currents in the atoms themselves which are permanent, which have nothing to keep them going, but which continue to go, because there is nothing to stop them, like the planets round the sun. In the old days people asked: " Where is the propelling force?" The answer of Newton and Galileo was, Nowhere: they require no propelling force. All they require is bending force—to bend them round in a circle—but, as far as their motion is concerned. they would continue by their own inertia without any compulsion, because there is no friction—no resistance and nothing to stop them. There we find matter doing what I have been speaking of an electric current as doing. The magnetic field round a current continues it, unless you cut the ring. That, of course, would stop it; or unless you heat it up, and that would stop it. There are many ways of stopping it, but if we do not stop it, it goes on.

So far it seemed only an analogy, but, in the year 1881 that remarkable man, Sir J. J. Thomson, now President of the Royal Society, Professor of Physics at Cambridge, Professor of Physics at the Royal Institution, London, and recently appointed Master of Trinity College, Cambridge, in the course of a youthful mathematical paper—for he was quite a young man in 1881—showed that an electrically-charged body had rather more inertia than if it were uncharged.

Take a sphere of radius A, and imagine that to be a metallic sphere on a glass stem. It has a certain mass, and weighs, let us say, a pound. Charge it with electricity. Weigh it again or measure its inertia; we find no difference. Why? Not because there is none, but because it is far too small to detect. Thomson calculated it, and showed that there would be a difference, and that, instead of being a pound, it would be a pound *plus* a million-millionth part of a grain—something absolutely, incredibly small, but not nothing.

Why should a charge on a sphere increase its inertia? Because a charged body, immediately it moves, is a current. There are many kinds of currents. An ordinary current is through a metal wire, but we can have a current through a liquid, where the atoms move and convey the current, and we can have a current by firing electrified bodies—moving electrified bodies at a high speed—or we need not employ a specially high speed. Directly it is a current, it is surrounded by a magnetic field; and directly it has got that magnetic field, it has got inertia. Given the data, we can calculate how much the inertia is, and Thomson showed that if the charge was E on the surface of the sphere of radius A, the extra or additional mass due to the charge was $M = (2E^2 \div 3A)$. That is to say, it depends on the square of the charge directly, so that it does not matter whether it is positive or negative. If the charge is doubled, we get four times the inertia, and it is inversely as the diameter or radius of the sphere. It depends on the charge and on its concentration. If we take the same charge and put it on a smaller sphere, the mass will be greater, because it is more concentrated; the denominator is less. Suppose we put the charge upon a body so small that it is hard to see it, the mass will be greater still.

That was the result in 1881—an interesting, curious, and apparently useless and not very significant fact, except to those who had eyes to see. However, it did not develop for a long time, for it was perceived that even if the body were so small as to be nothing but an atom of matter, still the mass would be almost negligible. An atom of matter is so small that 100 millions of them, and more, will lie in an inch lineally—immensely below anything we can see with a high-power microscope. There are more than a million million atoms in the smallest speck visible in a microscope, and a million million million atoms in the smallest particle we can see with the naked eye. An atom is incredibly small, and may be charged. There are many ways of charging atoms, but when we reckon by this formula how much the mass is increased, it is nothing worth talking about.

In 1889, however, Thomson discovered, or, rather, he isolated for the first time and experimented upon, the electron; that is to say, he split off from atoms of matter in a vacuum-tube particles much smaller than the atom—particles which were responsible for the electrical behaviour of the vacuum-tube. In the vacuum-tube electrons are flung at a tremendous rate, constituting what are called the "cathode rays." They have been spoken of as "atoms of electricity"; and they are called "electrons," meaning the unit of electricity—the unit below which there can be no charge. Electricity is found to exist in little lumps, in little countable things—each particle a unit, an invisible unit. Well, in 1899, these electrons were discovered experimentally—previously known mathematically—they were weighed, measured, and counted, and were found to be immeasurably smaller than atoms, so that compared with an electron an atom would be a gigantic thing.

If that represents an atom, said Sir Oliver (drawing a 2-foot circle), and that represents an electron (placing a dot beside it), then I have made the electron too big. If I made it the right size, you could not see it. If that dot were an electron magnified till you could see it, then the atom would be bigger than this room. Everyone knows that the sun is bigger than the planets, but that bears no sort of relation to these two things. The atom is small enough, but the electron, we might say, is too small, hopelessly small. Its size, however, is known. It takes 100,000 electrons lying side by side to make up the diameter of an atom, so that in bulk it is incredibly small. Well, if it is so small as that, and carries an electrical charge, what about this formula $M=(2E^2 \div 3A)$?

That formula now puts on immense importance. The A radius of the sphere is so minute that the mass of the body may be quite big—at least as big as the mass of the electron need be. In other words, it looks as if the whole inertia of the electron is explicable electrically—explicable by the magnetic field which is generated when it moves—that there is no ordinary matter in it at all, nothing but electricity, a disembodied sort of electricity, possessing inertia by reason of its magnetic field, and for no other reason. That is what it looked like, but it was not proved.

The proof came soon afterwards. The proof is a little complicated. I will not elaborate; I will merely say this. Paying attention to this formula now, more particularly than before, it is found that that expression is only a first approximation to the inertia of a charge—for if we work it out elaborately we get—

$$M=\frac{2E^2}{3A}\left(1+\frac{V^2}{2C^2}\right).$$

Here V is the speed of the moving electric charge, and C is the velocity of light. In other words, the inertia of an electric charge is not constant. Hitherto inertia had been thought to be absolutely constant. Here is a kind of inertia not absolutely constant, but slightly dependent on speed. If the body is moving with sufficient speed, its inertia increases; but the speed has to be very great, because it is to be compared with the velocity of light. A cannon-ball, of course, is not in it; no projectile is in it. Still, theoretically, the mass of the body does depend on the speed. If we could only get a speed up high enough, we might be able to detect the change in inertia; and if we could detect it, what a nice verification of theory that would be. It would show that this theory of electrical inertia is the true one, and would verify the result which was predicted—that the mass becomes greater when it is moving very fast. Is there no means of getting up these high speeds? We knew no methods of getting up anything like these high speeds. Singularly enough, a means has been recently discovered, not an artificial way, but a natural one. These high speeds are excited in the phenomenon of radio-activity. Radium and other radio-active materials and metals throw away fragments of their own—throw away electrons with a speed comparable with that of light, not quite the speed of light, but a half or even three-quarters of that of light. But take half. Suppose the speed of the flung-away particle is half: the inertia will increase by one-eighth of its value. Well, that is measurable. Suppose the speed is three-quarters: it will increase by about one-third. These measurements have been made; strangely enough, there are means of measuring them; and the results agree with the theory. The mass of these particles does increase, as the theory predicted; the inertia does depend on speed. Thus the electrical theory of inertia became established. So much for that stage.

But this is not yet the electrical theory of matter, because what I have so far been dealing with is electric charges. There is nothing to show that electricity and matter are the same; but in the most recent physics—some of it done since the war, but most of it done just before the war, because the war has been a great interruption to these researches—it has been found by a series of experiments, which it would take several lectures to make clear, that the atom, which is so much bigger than the electron, really consists in great part of electrons.

I must be content to give the result of these experiments.

rather than to explain how the facts were arrived at, and I must tell you that while, hitherto, I have been speaking of what is completely, and by everybody, accepted—that is, by physicists in all parts of the world—I have now to go into ground so recently covered, into discoveries so recently made, that there are still some differences of opinion as to detail, though very few differences of opinion, I think, as to the general probability of what I shall say.

The idea of an atom of matter which now holds the field is this. It consists of a nucleus of positive electricity, surrounded by a series of electrons in orbital movement round it, these electrons being each negative. If there were nothing but the negative electrons, they would repel one another, there must be something to hold them together, and the thing which holds them together is the positive nucleus, equal and opposite to the sum of the electrons. Why do they not fall on it? For the same reason that the moon does not fall on the earth though attracted to it with a tremendous force, but, instead, keeps on revolving round it; so these electrons revolve round the nucleus. The analogy is that of the sun and the planets, and the theory shows that there is in the atom nothing but electric charges—the negative electrons like the satellites, and the positive electron like the central sun. Most of the inertia of the atom seems to reside in the nucleus—some in the electrons. The atomic weight is made of the weight of the nucleus *plus* the weight of the electrons. The mass is made up that way. The positive and negative charges are equal: if there are three negative units, there must be three positive units.

I have told you what the electron is and about the way in which its speed varies. I have not said much about the positive nucleus—for a very good reason, I know very little about it. We know it is there, but we do not know its properties. It is a queer thing, that positive nucleus; there is a lot to be discovered about it. It is not a simple thing. Long ago it was thought, from spectrum analysis, that the atom had a complex structure. W. K. Clifford used to say it was at least as complex as a grand piano. Out of a grand piano you can evoke all sorts of notes; so with the atom all sorts of spectrum lines can be got. The rates of vibration of the piano notes can be studied acoustically; the rates of vibration of the atom can be studied optically, can be told by means of the spectrum.

There is growing up an astronomy of the atom. Just as Newton elaborated the theory of gravitation, and worked out not only the main orbits of the planets, but their variations, so the perturbations are being worked out in the atom. There are methods of perturbing them, as by collision, and when these collisions occur - the chemical clash of atoms—we get vibrations which can be studied in the spectrum. There are many ways of perturbing motion. As long as the motion is steady, there is not much to be said about it; we are surrounded by quiet atoms; but jostle them and make them chemically clash, and they give out radiation—light. And in that way the constitution of the atom has been made out.

The speed of electrons in the atoms is something tremendous. How do we know? Because there are methods of getting them flung away. If we subject an atom to *X*-rays, it is apt to fling away one of these electrons. The electron that is most likely to be flung away is the inner one, because it is going the fastest. It has to go faster not to fall in. When the right *X*-rays arrive, it is speeded up, it goes quicker, its mass is increased, and it flies away with a prodigious speed, something like that of light. When a body flies away at such an enormous speed, it must be for one or two reasons; it must be because there has been an explosion, an electric recoil, or it must be because it had that speed before, under control, and flies away at a tangent under a disturbing force with the speed that it had; and that last is what I believe to be the case. I suppose that the speed with which the electron is flung away is the speed which it had before. Therefore, imagine, if you can, these electrons travelling with something near the speed of light in orbits so minute that all are inside the atom. Imagine how many times they must go round in a second. The number of times they go round in a second can be estimated. To produce visible light they must go 500 million million times in a second, for 500 million million is the ordinary frequency of vibration that affects the eye. The number of revolutions per second in some *X*-ray cases is about a trillion.

Just let us trace some consequences which follow, if the atom is constituted in this manner. One consequence is that matter is exceedingly porous. Take the spaces of the sky. The solar system is characterized mostly by empty space. Here is a lump of matter, and there is a lump of matter, constituting the planets; but, for the most part it is empty space, so that if a comet goes through the solar system, it is pretty sure to miss everything; it might hit, but the chances are that it does not. That is what I mean when I say that the solar system is very porous—that it contains more space than matter. I say the same of the interior of an atom. The size of these electrons is so small that they have as much room to move in, in proportion to their size, as the planets have in the solar system. Consequently, if a small particle is thrown through an atom, the chances are that it will go straight through, making little perturbation. Matter is essentially porous. We can fling the electrons from a whole series of atoms through a sheet of aluminium—through any substance which is commonly called opaque. Matter is porous to an extraordinary degree—as porous as the solar system. Suppose there were hundreds or thousands of atoms in a row, the chances are that a flying particle would traverse them all. On the average about one in 20,000 hits the nucleus, and that stops it. The tracks of these particles have been seen, and it has been found that although they pass through a great number of particles, they do not pass through all. It is in that way that the existence of the nucleus has been established. If they hit the nucleus, they can not go on. In that way the massiveness of the nucleus has been etablished. In that way the constituton of the atom has been verified.

All the new facts discovered tend to strengthen the theory. There may be doubt about the details, but on present lines it is considered fairly established that that is something like the contitution or the structure of an atom. *X*-rays enable us to do more than that; they enable us to discriminate one element from another, and to count the electrons in the different kinds of atoms. For, when I say that "this is the constitution of an atom of matter," you would ask what sort of matter—hydrogen platinum, or lead; wherein exactly do they differ? Seven years ago I could not have told you; but there was a man of genius—Moseley his name was—who discovered that by using *X*-rays he could count the electrons in the atom and discriminate one atom from another. That work was led up to by Prof. Bragg, who had studied crystals by *X*-rays, but Moseley went further and studied the constitution of the atom. It is a magnificent piece of work, and has excited immense admiration. Moseley, alas! would volunteer for the war, and a Turkish bullet at Gallipoli pierced his brain; but his work remains, and I will try to indicate the kind of result he obtained.

He showed that the atom of hydrogen is a nucleus with *one* electron; you cannot have a simpler atom than that. The atom of helium has two electrons. Whether they are on the same orbit or different orbits, I am not sure. That is one of the things we do not know yet, and the simplest hypothesis is to put them on the same orbit. Next comes the atom of lithium, a nucleus with three electrons round it. The atom of carbon has six electrons; and now probably they cannot all be in one orbit: there must be more than one orbit in which they are revolving. That is the atom of carbon, and then there is sodium, potassium, chlorine, and so on. The whole series of chemical elements have been examined, but not completely. The heaviest atom known is that of uranium. There are 92 electrons in an atom of uranium—no more and no less—a nucleus of 92 positive charges, with 92 electrons revolving round it. It may be called a cumbersome thing, a complicated and unstable atom. It breaks down occasionally and tends to fling away a bit of the nucleus: it throws away atoms of helium; and when it has flung away three it becomes radium. It takes a long time to do it, however. Radium goes on with the process more quickly, and we get what is called "radium emanation." When it has flung away five atoms of helium, it becomes lead, and that is as far as we have got at present.

$$Ur - 3 \text{ helium atoms} = Ra$$
$$Ra - 5 \text{ helium atoms} = Pb$$

Thus, one would think that lead also would be radio-active; perhaps it is slightly, but it is very permanent, and, therefore, fairly common. In the case of lead, spontaneous activity seems to cease. Presumably, most atoms decay or break up sooner or later—I doubt whether any of them are absolutely permanent—but the common atoms are those which are most permanent, and, therefore, most common. It is like a community with a low death-rate; it has a large population.

The whole series of chemical elements—from hydrogen on the one side to uranium on the other—are thus planned out in a series. There can be 92 elements, and no more—unless there is one above uranium. There are only four or five exceptions—four or five gaps—and no doubt they will be filled before long. That is Moseley's theory. That is the most recent discovery in physics of which I am able to speak this afternoon.

Mr. A. M. Henshaw (Talke): It has been a very great treat and pleasure to all of us to be carried away into one of the romantic side-roads of science. I feel very much like one of the smallest and most insignificant of electrons after listening to Sir Oliver's account of such marvellous results of recent research in the science of physics. I once had the privilege of hearing Sir Robert Ball lecture on the solar system. That, of course, appears to be a subject impossible for the mind to grasp, because it is too big and too magnificent. This afternoon, however, we have had another phase put before us, which is absolutely too infinitesimal for the ordinary mind to conceive. It is certainly to me—and I am sure it must be to all of us—a mental recreation to have our minds led into channels such as those to which we have been directed this afternoon.

Mr. John Gregory (Sneyd Colliery): As an up-to-date mining institute we pride ourselves on what we are pleased to speak of as the "scientific" aspect of our industry. The science that we speak of is a very practical science, but Sir Oliver has to-day given us a peep into the fairyland of science; and it makes one wonder, after hearing Sir Oliver's description of atoms, whether the old alchemists were very far wrong after all—whether, by removing a certain number of these surplus negative electrons one might not get gold from lead. The whole subject is an exceedingly interesting one, and the lucid way in which Sir Oliver Lodge has explained a most abstruse theory has given pleasure to all the members present. The question that has so often been asked—what is electricity?—would apparently be on the way to solution if these theories are further investigated.

Sir OLIVER LODGE, in reply, said: It is true that I have been dealing with matters that do not come forcibly into practical life; at any rate, not at present. The last speaker suggested that this might be one way of making gold, but I fancy that practical men know of better ways, and I think that this would be a much more difficult and expensive method, even if it could be carried out.

But the alchemists were not so very far wrong, and in so far as they tried experiments and laid the foundation of chemistry, they were right. I sometimes think that they were not so keen about gold as they pretended to be; I think they were really keen about science—some of them—and that is a very different thing from cash, as those who have devoted themselves to science know. But if they had said in those ignorant days: "We are investigating things for the love of truth," or: "We are investigating Nature for its own sake," they would have been called lunatics and put on the fire and illtreated; and some of them were illtreated. If, however, they said they were making gold, then people would say, as they say now, "You are all right; you are quite wise." I sometimes think that is why they made that particular excuse. If a man stands on his head in the middle of the road, you think him a lunatic; but if he says he is doing it for a wager, then it is all right.

This is the fairyland of science, and, as Mr. Henshaw said, we have been dealing with the infinitely small, just as Sir Robert Ball had occasion to deal with the infinitely big. What impresses me is that they are so like each other. You will find the same laws running through both; the structure of the solar system and the structure of the atom are one. Sometimes I wonder whether absolute size has any real meaning. What we call "big" is something bigger than the human body, and what we call "small" is something smaller than the human body; but whether there is anything in real size or not, or whether there is anything in those speculations which have suggested that perhaps these atoms are each a solar system, or whether our solar system is but an atom of some larger unit, I do not know. Of all that I have no notion; we are working in the dark.

But I feel that everyone, however immersed he may be in practical and most useful undertakings, must like to refresh himself now and then by contemplating the laws and inner order of the magnificent universe of which we are a part, and in which our work lies. And the more we study it, the more immense its probabilities are. The extraordinary vistas opened to us in astronomy and in the depth of the sky are only equalled by the extraordinary vistas that loom before us when we penetrate into the innermost structure of the atom. We are confronted with infinitudes behind and before, and he is the wisest man who declines to put any limits to the possibilities of existence and keeps his mind open in every direction for new knowledge and new truth.

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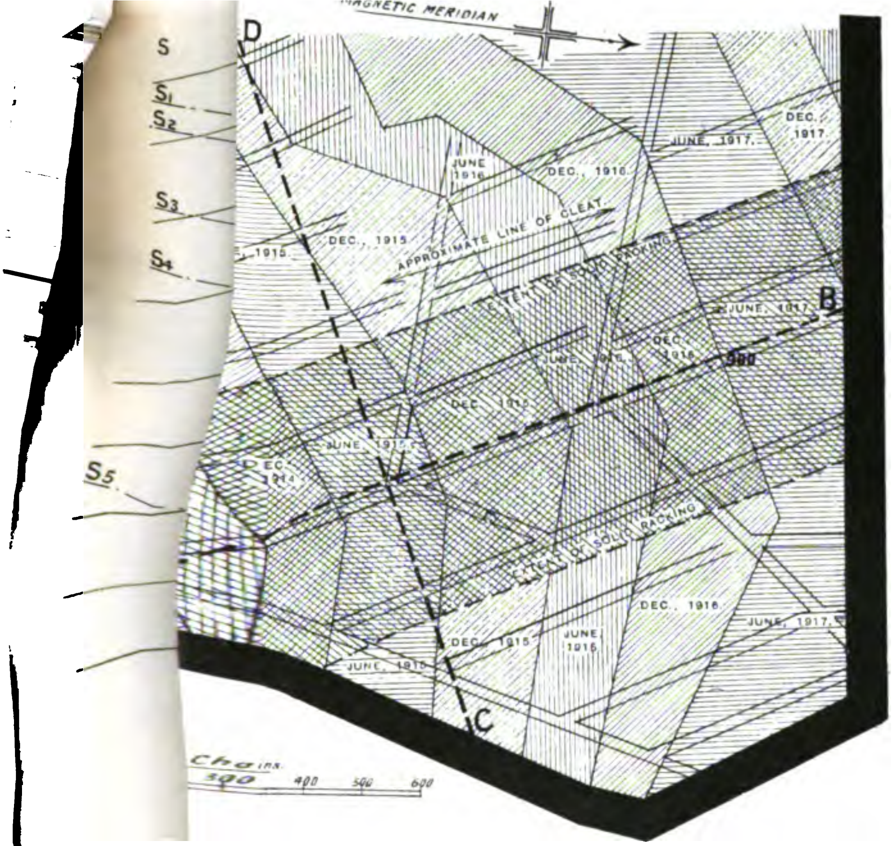
The Instit *Rocks and on the Surface."* VOL. LVII., PLATE II.

.—PLAN OF WORKINGS

FIG 1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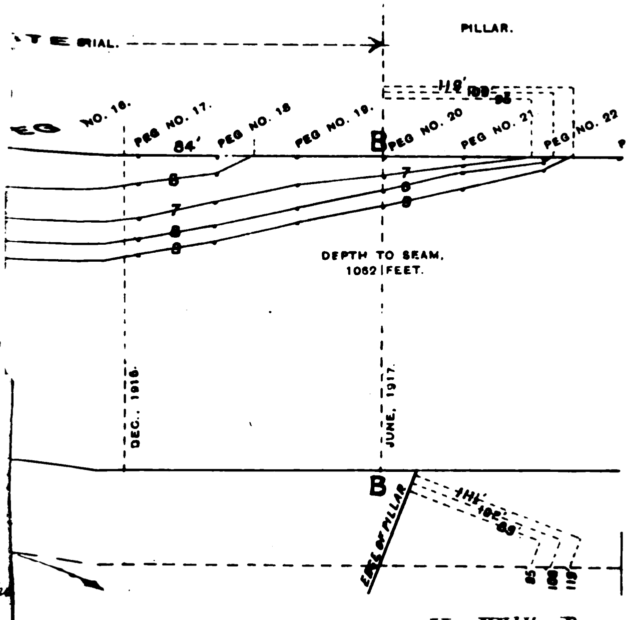
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VOL. XXIV., PLATE VIII.

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IN THE

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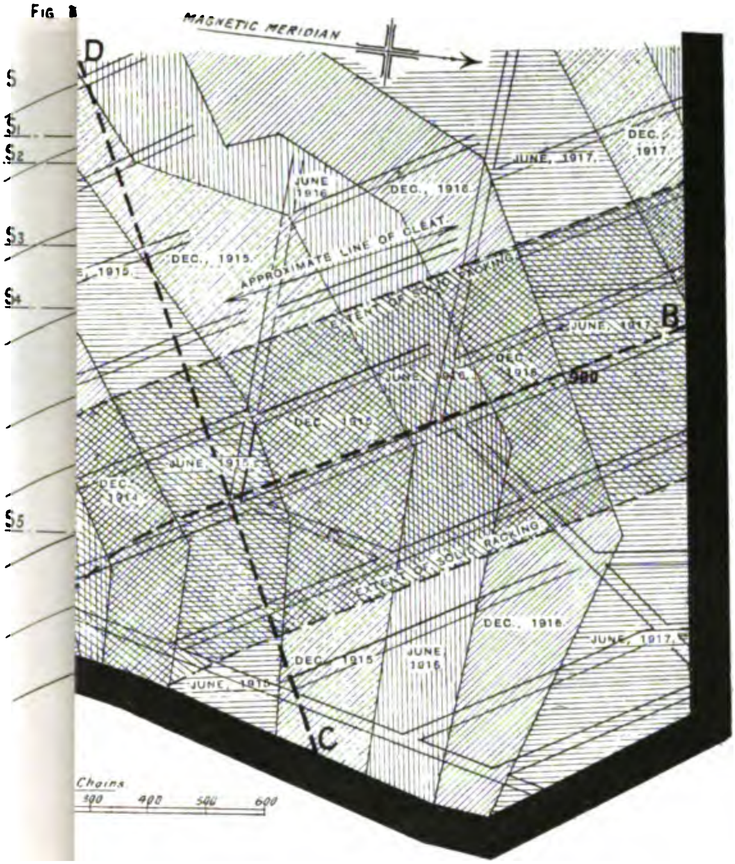
The Instit ***Rocks and on the Surface."*** VOL. LVII., PLATE II.

FIG. 8.—PLAN OF WORKINGS



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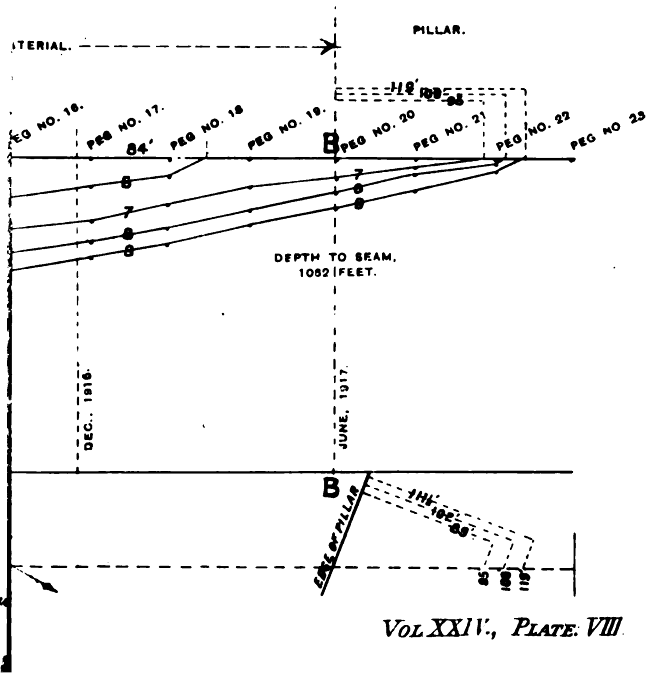

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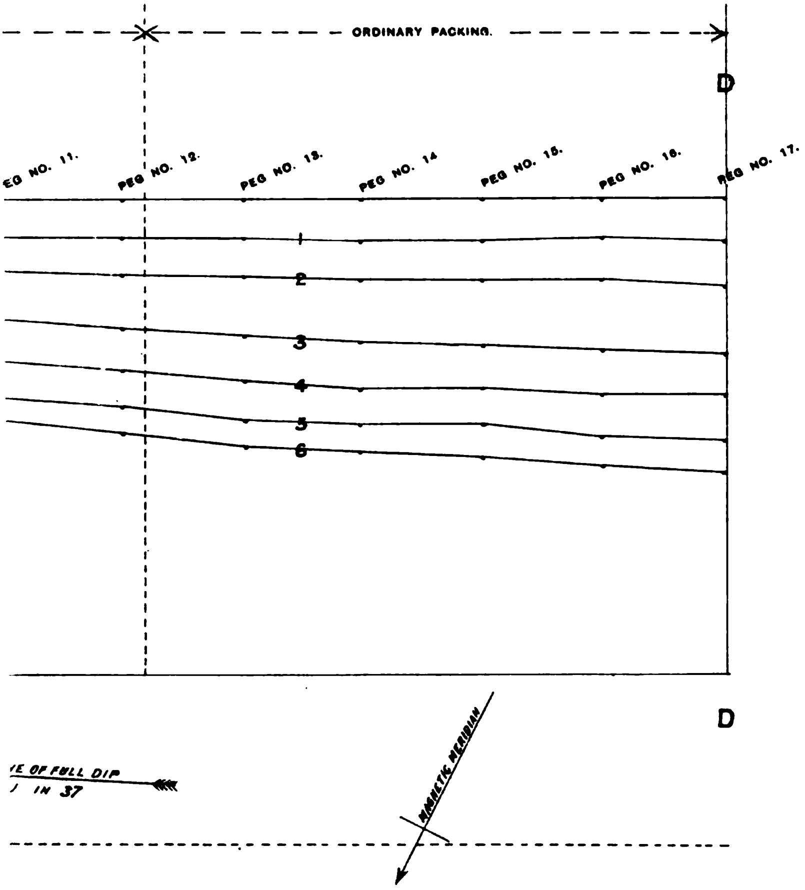
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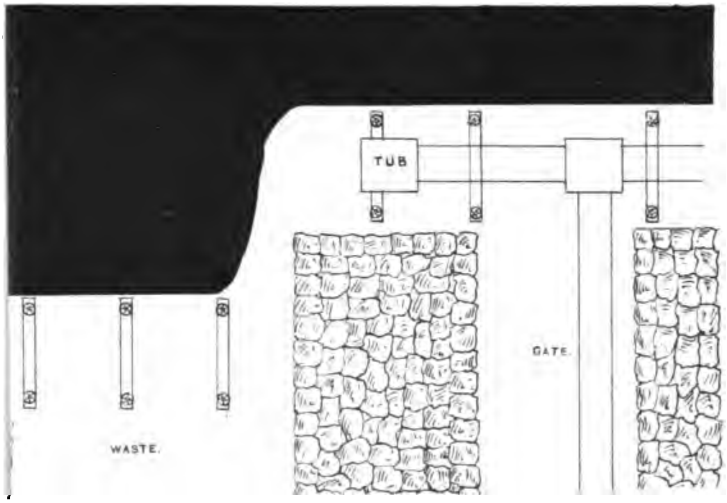
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Vol. XXIV., Plate, IX.

practical and most useful undertakings, must like to refresh himself now and then by contemplating the laws and inner order of the magnificent universe of which we are a part, and in which our work lies. And the more we study it, the more immense its probabilities are. The extraordinary vistas opened to us in astronomy and in the depth of the sky are only equalled by the extraordinary vistas that loom before us when we penetrate into the innermost structure of the atom. We are confronted with infinitudes behind and before, and he is the wisest man who declines to put any limits to the possibilities of existence and keeps his mind open in every direction for new knowledge and new truth.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

Held at the Central School of Science and Technology, Stoke-on-Trent,
April 28th, 1919.

Prof. Sir JOHN CADMAN, K.C.M.G., President, in the Chair.

PETROLEUM AND ITS OCCURRENCE.

Lecture by Prof. Sir JOHN CADMAN, K.C.M.G.

When I undertook this task, I gave to the Secretary a title the scope of which, I must confess, was somewhat wider than I appreciated at the time, and it was only when I began to consider the matter in detail that I found I had entered upon a subject to which it is almost impossible to do justice in the time at my disposal; indeed, I might turn to the members and ask whether there is anyone here who would venture to give an address to this audience on the question of coal and its uses, for my subject this evening is almost as broad. I am, therefore, going to confine my remarks to a very brief and cursory description of petroleum—its occurrence and uses during the war.

In the great war through which we have just passed no commodity has been more necessary to success than petroleum, and it is now abundantly clear that without supplies of petroleum and petroleum products the character of the war—with all its horrors and modern ugliness—would have been of a very different order. The importance of this subject will be realized when it is remembered that our fleet, the greatest and most powerful that the world has ever seen, could not possibly have been brought to its present state of efficiency without the use of liquid fuel. Our army and the armies of our allies could not have been transported, supplied, and fed without petrol. Hostilities have taken place, for the most past, in areas not served by a network of railways running to strategic positions, so that transport largely depended upon a supply of petrol. Furthermore, the Royal Air Force relied upon the light petroleum fraction known as "aviation spirit." In addition, the manufacture of munitions on a colossal scale was rendered possible only by the provision of supplies of mineral lubricating oils, while a great proportion of high explosives were obtained from petroleum derivatives. Necessary as abundant supplies are in time of war, the more so are they necessary for the efficient conduct of our commerce and industry in time of peace.

Some fifty years ago, the supplies of petroleum were practically *nil*; half the world literally lived in darkness, and without any conception of our modern means of transport. In fact, even in America, which now produces the bulk of the world's supply, petroleum was only known 60 years ago as a " cure for all ills," advertised by some enterprising apothecary. The history of the petroleum industry is almost a romance—and its development, although already phenomenal, is destined to be of such magnitude and importance that it is impossible to set bounds to its future domain.

Before speaking of the history of the industry, you will, I know, pardon me if I explain in the first place in a few words what petroleum is and how it is found in Nature. In its crude state natural petroleum is a complex mixture of hydrocarbons, only dissimilar in molecular degree from the complex hydrocarbons of which coal is composed. The hydrocarbons which constitute the main bulk of most petroleums belong to what is known as the " saturated " paraffin series, and this family commences with the gas methane. The first four members of this series, starting with methane (CH_4), are gases; the next three—pentane, hexane and heptane—are highly volatile liquids, constituting the bulk of " petrol "; and some petroleums contain also the olefine series—ethylene (C_2H_4), etc.

Whether the origin of petroleum be organic or inorganic, animal or vegetable, matters not for the purpose of this descriptive lecture, but the search for oilfields necessitates a careful study of its probable origin. Being a liquid, and therefore capable of migration within the pores of the containing rocks, petroleum can be concentrated within geological boundaries, and it is to this characteristic that commercial supplies of natural petroleum are possible. For the concentration of petroleum suitable geological structures are necessary—that is, a containing rock, with good porosity, and above it an impervious roof or covering. The most favourable structures are anticlines, faulted monoclines, or bedding which has had its porosity sealed and has allowed concentration by arresting migration and loss of the liquid petroleum through outcrops. Oil is usually concentrated by floating on water, and is in this way confined to the high places of the rock structures. These are the conditions, in so far as our present knowledge goes, under which oil is conserved, and these are the conditions which the geologist looks for in selecting the areas in which trial drillings are to take place.

Let me now turn to the history of the petroleum industry. Petroleum has been known from time immemorial, but it was not until it was secured in a boring put down by Drake for the New Haven Company in 1859, in what was known as the Oil Creek property, that the possibility of working natural petroleum deposits was established. Ten years or so before that date natural petroleum had been discovered at Riddings Colliery in the Midlands, and it was the attempt to treat the oil for the manufacture of a suitable illuminant that gave birth to the oil-shale industry, originally commenced in the Midlands in 1847, and afterwards carried to Scotland by Young. I mention this because it is of great interest when considering the evidence upon which the present drilling for oil in this country is being based, and I shall refer to it again later.

In 1859 Drake, although only drilling to some 69 feet, introduced metal casing into his borings in order to protect the sides and shut off the water, and although his methods were primitive to a degree, yet the fundamental principles underlying modern petroleum drilling systems are largely the same. The Institute will, I hope, have an opportunity of visiting the boring which is now in progress at Apedale, when the methods in vogue will be examined personally, and I do not therefore propose to take up your time in describing the procedure in any detail.

I have explained how petroleum is forced by hydraulic pressure into the crests of anticlines, and is there concentrated. It is obvious, therefore, that it is imperative not to allow water to accidentally enter the oil-sand, otherwise a good source of supply may be rendered commercially unprofitable by admixture with water, or altogether dissipated. Consequently, it becomes necessary to shut off and seal back all water-bearing horizons that may be passed through in the process of boring for oil. This is one of the most important and difficult problems which the driller has to face, and where inefficient and bad work is carried on, an oilfield may be entirely ruined by the careless operations of one incompetent driller.

Sir John Cadman proceeded to describe, by means of photographic lantern-slides, illustrative of the United States, Canada, Persia, and Trinidad, the various topographical and geological conditions under which oil is obtained; the manner in which boreholes are drilled; the collection of boreholes to obtain production and output; the collection and distribution of oil from the wells to the tanks, and thence to the refineries; the method of refining and production of the various grades of petroleum products; and the various oilfields of the world.

Dealing with some of the problems which had to be faced in providing sufficient supplies for the prosecution of the war, the President exhibited graphic charts showing the position in regard to petroleum supplies in 1917—consumption, stocks, and danger lines. Then, as Lord Curzon had pointed out, there was only about a month's stock in the country, and the fleet's exercises had to be curtailed. Thus, in 1917, we were in peril, but just before the Armistice was signed the curve of stocks had gone up considerably, and we were well out of danger.

One may now ask why an attempt is being made to drill for oil in this country, and what is the evidence upon which this effort is based. I have already indicated the perilous position in which we were placed in 1917, from which it was clear that no stone should be left unturned which could possibly relieve the situation.

A good deal of geological work had been done by Lord Cowdray's staff in reviewing the possibilities of obtaining natural oil in this country, and in this connexion special credit is due to Dr. A. C. Veatch, Messrs. Pearson's chief geologist, who was always of the firm opinion that oil existed if only suitable structures were tested by the drill. As Lord Cowdray was preparing to test these deductions by drilling, it became a subject of supreme national importance that the test should be made without delay, for, if the war continued, and if the deductions were well founded, the obtaining of natural petroleum beneath our feet offered a most attractive solution to the overwhelming difficulty of meeting our ever increasing demands.

The theory advanced in support of the existence of petroleum may be briefly summed up as follows:—

(1) There exists in this country, beneath the Coal-Measures, geological structures eminently suitable for the concentration of petroleum—porous rocks, with impervious covering, suitably folded; indeed, all the physical conditions are admittedly present for the conservation of the product.

(2) There is evidence that an oil phase has existed in the rocks of this geological horizon. This evidence occurs in the shape of the oxidized remains of petroleum in the outcropping rocks, and also in the percolation of small quantities of oil in certain coal-mines in this country.

(3) There is only one case where suitable structure existed in which a borehole had penetrated into this horizon, and in this case natural petroleum was discovered.

A *prima-facie* case has been established for the test, and whether or not petroleum will be found in commercial quantities is a question that can only be answered by the drill.

The President, in concluding, quoted the following comparisons and statistics:—

COMPARISON OF OIL WITH COAL.

1 ton of oil takes up 36 cubic feet.
1 „ of coal „ 43 „
10 pounds of water evaporated from and at 212° Fahr. per pound of coal.
16 pounds of water evaporated from and at 212° Fahr. per pound of oil.

Calorific Value.

Oil 14 to coal 10, or
Oil, 19,000 B.Th.U.; coal, 14,000 B.Th.U.

For Marine Purposes.

100 tons of coal is equal to 66 tons of oil when used for the production of steam.

100 tons of coal used as steam is equal to 25 tons of oil used in internal-combustion engines.

The earning capacity of a ship like the *Mauretania*, bunkered with oil instead of coal, with coal at 18s. 6d. and oil at 37s. per ton, is increased by £250.000 per annum.

OUTPUT OF OIL IN 1917.

	Gallons.	Gallons.
America.		
U.S.A.	45,000,000	
Mexico	8,250,000	
Peru	350,000	
Trinidad	225,000	
Argentina	175,000	
Canada	30,000	
		54,030,000
Europe.		
Russia	9,500,000	
Roumania	1,000,000	
Galicia	900,000	
Germany	150,000	
Italy	7,500	
		11,557,500
Asia.		
East Indies	1,800,000	
India	1,150,000	
Persia	1,000,000	
Japan	400,000	
		4,350,000
Africa.		
Egypt		134,000
Shale-oil.		
Great Britain	250,000	
Australia	5,500	
		255,500
	Total ...	70,327,000

Mr. A. M. Henshaw (Talke): Will you give us, Sir John, some little explanation of the origin of mineral oils?

Sir John Cadman: I kept away from that point because it would take up so much time, but it might be useful to have a discussion on it at some future meeting. The oilfields of the world can be confined practically within two narrow geological periods—the Tertiary and the Carboniferous.

Mr. **HENSHAW**: How many of the oilfields of the world have been discovered by geological reasoning? Is it not a fact, however, that most of the existing oilfields have been discovered by accident, or owing to the appearance of oil on the surface—in other words, to a seepage? Is it not also a fact that only recently have geologists searched by geological evidence?

Sir **JOHN CADMAN**: It has been so much of a wild-cat quest that wherever evidences of oil have appeared people have attempted to drill, irrespective of the geological boundaries. It is only within recent years that it has become a definite science; indeed, our knowledge of the conditions under which oil is formed are not even now what they should be. Geological work in connexion with oilfields is only of recent years, and it is impossible to say how many fields have been discovered by direct geological reasoning. But to-day money is very rarely spent without a previous and careful geological examination. The science is young and offers a great opening, for when the great demand for oil is borne in mind, and you look at a map of the world and see that the earth has only just been scratched in the search for oil, you will realize the immense possibilities before us. The world is vast, and a great deal of it has not even been examined geologically or by anyone who has a knowledge of oil. My own view is that many of the great oilfields of the world still remain to be discovered.

Mr. **HENSHAW**: Sir John Cadman's Address is particularly interesting to us, because our business lies with some of the mysteries to be found in the crust of the earth. I hope myself that we shall find oil in this country, for it seems more than ever necessary to-day. If, as a result of the findings of the Coal Commission, the coal industry is to be crushed, we shall have to find a substitute for coal. The nineteenth century might be called the " Coal Age," and now we are seeing the birth of the "Oil Age," for this new industry has a great future before it. Unknown oilfields of great magnitude may be discovered, and provide the source of heat and power for the whole world for another generation. It is a credit to our Institute that our President is one of the greatest experts on oil in the world, and is recognized as such by the Government, and that he has been Chairman of the Inter-Allied Petroleum Council, which has had charge of the whole of the oil supplies for the Allies. Moreover, I believe Birmingham is the only University where there is a Chair for the study of petroleum.

Sir JOHN CADMAN, in reply, said: It has been a great pleasure to me to have the opportunity of addressing the Institute, although I fear I have not done justice to the subject, trying, as I have done, to cover this vast subject in an inadequate space of time, but I have indicated to you the magnitude of the subject and its importance to the industrial enterprise of this country. I hope at a future meeting we may be able to traverse the ground a little further, and see how oil is used and applied. Mr. Henshaw has expressed the hope that oil may be found beneath our feet, which, as I say, although uncertain, promises well, and whilst I have avoided expressing an opinion, I have given you the facts. This is a different problem from coal-mining, although there are parallel features.

THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,

Held in the Rooms of the Society, Queen's Chambers, 5, John Dalton Street, Manchester, May 13th, 1919.

Mr. A. J. A. ORCHARD, President, in the Chair.

THE PRESERVATION OF MINE TIMBER.

By N. T. WILLIAMS, B.Sc.

Introduction.—The subject of this paper is of supreme importance at any time, but more especially so just now, for it is evident that we shall not for many years, if ever again, have cheap timber—that is, as we understood the term in pre-war days. The question, therefore, of timbering with due regard to economy in the use of material is a pressing necessity, and it is but wise to investigate the situation and adopt conservative methods whenever possible. Owing to the scarcity of timber, it is not possible to procure the more durable kinds, but it is a poor policy nevertheless to use unsuitable and unseasoned timber, as that would but increase the demand on an already decreasing supply, enhance the cost and that of labour through frequent renewals, and cause an increase in the number of accidents.

Considerable waste is incurred by placing untreated timber in situations where it is liable to rapid deterioration by decay, and by the non-recovery of props in goaves which in many cases could be withdrawn with safety. In the United States of America the Forest Service, in co-operation with various mining companies, has carried out a number of investigations: (1) " To determine suitable methods of treating timber used in mines "; and (2) " to determine the durability of treated and untreated timber in actual service." Mr. E. W. Peters (13)* estimates that of the total quantity of timber used in mines 50 per cent. is wasted owing to decay and insects, 25 per cent. is wasted in gobs, abandoned workings, etc., whilst breakage and wear account for the remainder. There are no figures available relating to the wastage of timber in the mines of this country, but it seems very probable that decay is by far the most important factor in damp mines. We have, however, statistics (18) of the quantity of timber used for mining purposes.

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*The numbers in parentheses refer to the bibliography in the Appendix.

In normal circumstances the total amount of pitwood consumed annually may be taken as approximately 4,500,000 tons, or roughly 1 cubic foot of timber per ton of coal produced.

Wastage through decay takes place more especially in shallow and damp mines and in certain parts of deep mines which are damp. Much of this loss could be prevented economically by some form of preservative treatment of the timber. It would, of course, be waste of money to employ antiseptic material for timber to be used at the working-face, or in dry and deep mines, where owing to pressure it would break long before any decay would take effect.

The decay is caused by "fungi" and "bacteria," which are dependent on wood for their food, and have the capacity to penetrate the cells and destroy the fibre of the wood. The disease is spread by their microscopic spores to sound wood, which is ultimately destroyed. It is unnecessary to deal further with this matter, as two excellent papers on the subject have been recently contributed to the *Transactions* (5 and 6). For the fungus to exist, it must have a definite amount of food, moisture, air, and heat. If the food supply is poisoned, or the moisture content of the wood is reduced below the amount required for the growth of fungus, through seasoning and using it in a dry mine, or through the exclusion of air owing to the wood being permanently wet, decay will be prevented as long as any of these conditions prevail.

The practical method for satisfying all these conditions is to treat the timber with a suitable antiseptic that will act as a germicide and exclude both moisture and air, for as long as the effects of the preservative last the timber will be sound. Timber cannot be preserved permanently if the agent used as an antiseptic and waterproof is itself volatile in air or soluble in water. Timber treated with a soluble preservative, such as chloride of zinc, when exposed to a damp atmosphere will eventually leach and the wood will be left unprotected.

Preparation of Timber.—Timber to be used in permanent roadways should be peeled even if not intended to be treated. This will increase its durability, as the bark retards the escape of moisture and harbours fungi and insects. For the antiseptic process, the bark must be removed before it can be successfully treated.

Seasoning.—The object of seasoning is to expel the water contained in the sapwood and cell walls, and thus increase its strength and durability. According to Mr. Weiss (20) air-dry lumber containing 8 to 12 per cent. of moisture has about twice the strength of green wood. As long as the timber remains dry, it is proof against decay. In wet mines the effects of seasoning are nullified by the absorption of moisture. Mr. Peters (13) gives the loss of weight of green wood as 15 to 35 per cent. when piled and exposed for 8 weeks to a free circulation of air. The open-air seasoning is generally adopted in the United States in order to make the timber more porous for the introduction of the preservatives. From two to four months is necessary for open-air seasoning (12); but length of time is dependent on a number of circumstances—the kind and size of wood, the time of the year, etc. Careful stacking is required, so as to secure the free passage of air, and the yard should be free from decayed timber. For rapid seasoning, artificial methods can be adopted, such as seasoning in saturated steam or seasoning in creosote. In order to remove the water and air from the wood, a vacuum is drawn.

Peeling and seasoning increase the durability of the timber, but in order to render it immune from attacks of fungi, a preservative treatment is necessary. The chemical used should be a germicide and should exclude the moisture necessary for fungoid growth.

In the preparation of this paper I have perused a number of separate publications in order to secure reliable information on the subject, and reference to these is made in the text.

Preservative Treatment.—The art of timber preservation on an extensive scale began with the development of the railway system, which made a large demand on timber, especially for sleepers; and as these decayed rapidly, some method of prolonging their life became a positive necessity.

Mr. Boulton in his paper (1) states that " by the year 1838 four several systems of antiseptic treatment were fairly before the public. These were corrosive sublimate, introduced by Mr. T. H. Kyan, sulphate of copper, by Mr. J. J. Lloyd, margary, chloride of zinc, by Sir Wm. Burnett; heavy oil of tar (afterwards called creosote), by Mr. John Bethell."

Many other chemical preparations have been experimented on and tested with more or less success. It may be mentioned that for the past eleven years good results have been obtained in Austria in treating telegraph-poles with sodium fluoride, which is comparatively cheap. Its advantages over zinc chloride are its high toxic properties and its lesser liability to leach from the wood, whilst its corrosive action on iron is also less. Mr. C. H. Teesdale (16) states that several mine and railway sleepers were treated with fluoride and installed in January, 1914. It is now in commercial use in the United States of America. The antiseptics most extensively used at present are creosote and chloride of zinc, which have proved very satisfactory. Mercuric chloride or corrosive sublimate is unsuitable, as it is poisonous to handle, volatile, and very soluble in water. Nor can copper sulphate be used in a treating plant, because of its corrosive action on iron.

Method of Application.—The method of applying a chemical treatment depends on a number of factors, such as the quantity of the timber to be treated, the kind, and the conditions under which it is used. When the quantity to be treated is small, a brush treatment with two coats of hot carbolinium, creosote, or any other standard antiseptic applied to sound seasoned timber, will be found economical. By this treatment its life may be considerably extended—very often at least doubled. The effectiveness of this treatment, however, depends on the seasoning, how thoroughly the cracks in the timber have been filled, and on the length of time the coating will remain unbroken. If the timber were dipped in a hot solution (about 180° Fahr.) in a tank, better results would be secured than by brush application, as all the cracks would be better filled with preservative. In order to secure deeper penetration, an impregnation process must be used—either the open-tank or the pressure treatment.

The Open-tank Method.—The process consists in steeping timber under atmospheric pressure in a hot solution of creosote (maximum temperature, 220° Fahr.) or zinc chloride (maximum temperature, about 212° Fahr.; strength of solution, 4 to 6 per cent.). The timber is kept submerged for various lengths of time, depending on its character and size, moisture content, and the penetration desired, but generally for seasoned timber from 1 to 4 hours. After the hot bath, the timber is immersed in a cold preservative in another tank, or allowed to remain in the cooling liquid; or the hot liquid is run out at the end of the hot bath and sufficient cold liquid is admitted to cover the timber. The time required for the cold bath ranges from 1 to 8 hours, according to the penetration required. For well-seasoned and porous wood the cold treatment may be dispensed with. The theory of the process is that in the hot treatment the heat of the preservative expands and expels a portion of the air in the cellular spaces of the wood-tissue, and that some of the water contained, mainly in the outer layers of the wood, is driven off. On the rarefied wood being immersed in the cold bath, or when allowed to remain in the cooling liquid, the preservative is forced by atmospheric pressure into the cellular structure of the wood, a process assisted by capillary attraction. By this method deep penetrations of the preservative are possible in certain kinds of seasoned timber.

It is possible to impregnate timber with creosote alone, with zinc chloride or sodium fluoride alone, or a combination of creosote and a metallic salt. Thus by boiling the timber in creosote and subsequent immersing it in the salt solution the treatment will be carried out at a lower cost than if creosote alone were used, and the outer layer of the wood will contain some of the creosote.

When a small absorption of the liquid is required, the timber should be left in the cool liquid only a short while after it has been removed from the hot bath.

The plant required is simple and inexpensive. It comprises an open tank, which may be an old boiler-shell or a rectangular steel tank, a storage-tank, a pump, and the necessary piping. A second tank may be added for use in submerging the timber in a cold solution.. The tank is mounted on a brick wall with a firebox and flues.

Better control of the heat is, however, obtained if steam is passed through coils in the bottom of the tank. The tank may have a door at one end and a line of rails fixed in the bottom. The wood to be treated is then run in and out on cars, and the top of the tank is covered with boards. Fig. 4 in the text illustrates an equipment for open-tank treatment.

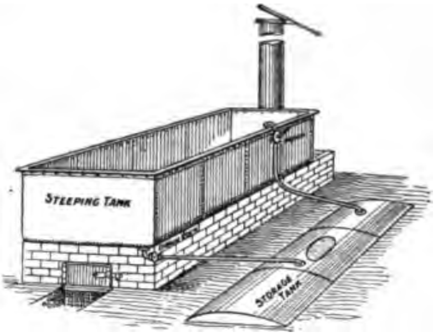

FIG. 4.—OPEN-TANK PLANT FOR TREATING TIMBER IN HOT AND COLD BATHS.

The open-tank process has given very satisfactory results, the cost of the treatment is relatively small, and the equipment necessary comparatively simple. Under average conditions it would seem to be the process to be recommended for the required treatment of mine timber.

As most of the timber to be treated consists of round props, which have a zone of porous sapwood surrounding the heartwood, the sapwood of the timber generally used in mines can be penetrated with a preservative without the application of pressure. But for sawn timber, such as sleepers, etc., where both sapwood and heartwood surfaces are exposed, and for a more uniform impregnation of the heartwood as well as of the sapwood, the pressure process has to be employed. Generally, the installation of such a costly plant would not be justified at individual collieries, as it is not suitable for the treatment of small quantities. But economy could be effected by the various colliery companies erecting a central pressure plant at the most convenient spot in the locality, which could deal efficiently with considerable quantities of timber.

The cost of treatment then would be considerably less than if each company did the treating at its own colliery, while different classes of timber (which vary widely in their resistance to the penetration of antiseptic liquids) would be treated separately, and more uniform results thereby obtained.

The essential units of a pressure plant consist of a retort, a storage-tank, pumps, a boiler, and necessary accessories. Figs. 1, 2, and 3 (Plate IV.) illustrate some of the features of such a plant. The retort or impregnating cylinder is invariably built of steel, having a diameter of from 5 to 7 feet and a length of from 20 to 150 feet. It is fitted with a track for the cars to run on and guard-rails to prevent them from being derailed when the cylinder is filled with the preservative; steam-coils are fixed at the bottom along the entire length of the retort for heating the preservative. The door of the retort may be hinged and bolted to the cylinder, or supported by a crane, which enables it to be swung out of the way during the transfer of cars.

The storage-tank is used for storing the preservative, and into it the liquid is allowed to drain from the retort after the timber has been treated. Two pumps are required—a vacuum pump for exhausting the air in the retort after the timber has been admitted and while the preservative is being introduced, and a force pump, which is used for moving the preservative and maintaining it at the desired pressure until the timber in the retort is impregnated to the extent required.

The principal factors influencing the absorption of preservatives are the kind and condition of the timber. Green or insufficiently seasoned timber is subjected to steaming (maximum temperature, 260° Fahr.), or boiling in creosote (maximum temperature, 220° Fahr.), and then subjected to a vacuum of 20 to 26 inches, the air-pump removing the water in the form of vapour and the air from the cells. This prepares the pores for the the reception of the preservative, which chokes the pores and renders the timber impervious to water and air, and is poisonous to parasites. If the timber is properly seasoned, the steaming is omitted, but it is desirable to have a vacuum drawn to remove the air.

Operation of Plant.—The operation of the plant is simple. The timber is run on cars into the horizontal retort and the doors secured; the timber (if green) is first subjected to a preliminary steaming; it is then subjected to a vacuum and held while the preservative is introduced and continued until the retort is filled. The temperature (about 160° Fahr.) in the retort is sufficient to liquefy any suspended constituents. The antiseptic is now subjected to a pressure of about 100 pounds per square inch until the desired penetration has been obtained. The taps are then opened and the preservative drained into a storage-tank; when this operation is completed, the door of the retort is opened, the treated timber is allowed to drip for a short time, then removed, and stacked to dry. The retort is then ready to be recharged. In order to assist the drying, the timber is sometimes subjected to a vacuum for a short time before it is removed from the retort.

The time required for treatment will vary according to the condition, size, and kind of wood, and the degree of penetration desired. For the creosoting process, with an absorption of 5 to 12 pounds per cubic foot, the time occupied for the different stages of the treatment is as follows:—Steaming, 2 to 4 hours; blowing off, 15 minutes; vacuum, $\frac{1}{2}$ to 1 hour; hot creosote under pressure, 1 to 2 hours; forcing back solution, 15 minutes; vacuum, 15 minutes; total, 4 to 8 hours.

The treatment with chloride of zinc is carried out in the same kind of plant, the stages in the process being analogous to those in the creosoting treatment. The strength of the solution generally used varies from 3 to 6 per cent.

Other methods are sometimes employed to effect economy in the amount of chemical required. Thus the interior of the timber may be impregnated with the less expensive chloride of zinc, which is in turn protected from the action of water by treating the outer zone with creosote. The principal advantages of chloride of zinc compared with creosote are: cheapness, more resistance to fire, cleanliness in handling, and freedom from odour. There is also a saving in carriage, as the chloride is supplied dry and in a concentrated form. Under like conditions, zinc chloride will penetrate the wood more readily than creosote. The cost of the treatment with the latter is two to four times that of the former.

The chief objections to the use of chloride of zinc are its tendency to leach from the timber in wet situations, and its slight corrosive action on the steel retort and on nails and spikes driven into the treated timber. In mines relatively dry, however, chloride of zinc gives excellent results; on the other hand, creosote obtained from the higher fractions of the distillation is insoluble in water, non-volatile, and forms an imperishable substance for treating timber.

For the best results in creosoting, great importance is attached to the effective quantities of light oil, naphthalene, and anthracene oil contained in the creosote. The specification of the General Post Office for creosote used for treating telegraph-poles contains the following stipulations (21):—

(*a*) To leave not less than 25 per cent. or more than 35 per cent. residue when distilled up to a temperature of 316° Cent. (600°8 Fahr.).

(*b*) To contain not less than 15 per cent. of naphthalene.

(*c*) To contain not less than 5 per cent. of phenol and other phenoloids.

(*d*) To be completely liquid at 38° Cent. (100° Fahr.).

(*e*) Not to contain more than 2 per cent. of matter volatile at 100° Cent. (212° Fahr.).

I am indebted to Messrs. George Black & Sons, Berwick-upon-Tweed, for the drawings for Figs. 1 to 4.

APPENDIX.—Bibliography Relating to Mine Timber and Preservative Methods.

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THE MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
Held in the Rooms of the Society, Queen's Chambers,
5, John Dalton Street, Manchester,
June 17th, 1919.

Mr. A. J. A. ORCHARD, President, in the Chair.

DISCUSSION OF MR. N. T. WILLIAMS'S PAPER ON "THE PRESERVATION OF MINE TIMBER."*

The President (Mr. A. J. A. Orchard): Can Mr. Williams give figures of the cost of treated timber as compared with untreated timber, and information as to the underground conditions under which treated timber has been used? The conditions in the collieries vary: what may be successful at one colliery will not necessarily be so at another; so that any statement of cost should specify the conditions under which the timber is used.

Mr. F. N. Siddall (Atherton): Creosoted timber was used at a colliery at which I was employed. The colliery was very wet in some places, and the coal was subject to gob-fires. Judging from my experience there and elsewhere, it seems that timber rots more quickly in places where the oxygen content in the air is deficient.

Creosoted props were tried which were specially prepared and about as well impregnated as telegraph-posts. They lasted from five to seven times as long as the ordinary mining timber set in the same place. I cannot give any figures of cost, but even if the cost was proportionately as great, one has to take into consideration the saving in labour of repairing the roads. These props were set in places which were very wet, and in others which were apparently dry but in which timber rotted fast on account of the dampness of the return air. I tried the air with different hygrometers, with the curious result that on several occasions the wet-bulb reading was higher than the dry-bulb reading. The air was super-saturated. The props were a success in the main return airways where the ground had settled, but were useless where there was any " weight " or movement of the strata, as they proved very "short" and would snap without warning. Creosoted timber is unsatisfactory when used as bars, and breaks very quickly under pressure.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvii., page 125.

The conclusion I came to was that the use of creosoted props would pay very well in places where timber rotted very fast if such places had no " moving weight " on them. During my mining experience I have come across seams—notably the Ince Seven Feet Seam of Lancashire—in which the timber appears to rot inordinately fast, probably owing to the presence of some gas or emanation in the air, or to the absorption of oxygen by the coal.

Mr. C. FLETCHER (Atherton): We used creosoted props for a short time in the main return airway of a shallow mine, where a fungoid growth appeared on the timber and rotted it considerably. About ten years ago we bought some props already creosoted, and others were steeped by ourselves, and although I cannot supply definite figures, yet I know that these props lasted much longer than the ordinary props. There was no weight on the road in our case, so that I cannot say what the effect would be if they were subjected to a heavy weight. They were not tested in any way, and the road was not maintained very long. They certainly served their purpose, and lasted three or four times as long as ordinary timber. We have not tried creosoted sleepers.

Mr. ARTHUR MILLER (Manchester): My own experience in workings 800 or 900 yards deep and in the main return where it was damp is similar to that of Mr. Siddall. In places where there was not much weight to be carried, creosoted timber proved satisfactory; but where there was a heavy weight to be carried, the props snapped, so that they were really of no service. Even in places where there was little weight, the props would occasionally snap. Ultimately, the creosoted timber was taken out and steel girders were put in.

Mr. N. T. WILLIAMS (Manchester): I have no figures to show the comparative cost of treated and of untreated timber, but in the bibliography attached to the paper there are a number of papers in which costs are given. In the course of the discussion of Mr. R. Martin's paper* the cost of treating timber in the open tank (salt solution) is given as 1¼d. per cubic foot, while the life of the treated timber is stated to be many times as long as that of untreated timber. This has been proved to be the case both in Scotland and in the United States.

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* *Trans. Inst. M. E.*, 1895-1896, vol. x., page 531.

In *Mines and Minerals* for October, 1918, figures are given showing that in America the open-tank treatment with creosote worked out approximately at 2d. per cubic foot; the brush treatment, at ¾d. per cubic foot; and the cylinder treatment under pressure, at 7½d. for 10 pounds of creosote per cubic foot. That system of treating timber would be very expensive for collieries, and that is why I suggested in my paper that the open-tank process would be the most suitable

The cost of creosote oil was given as 6 to 9 cents per gallon. The treatment with zinc chloride would be much cheaper—about a third of the cost with creosote.

The question of brittleness is rather interesting. I have never known of an instance of brittleness being due to the treatment of the timber, unless it is subjected to a high temperature. If care is taken that the oil in the course of boiling does not exceed a temperature of 220° Fahr., the tests for bending and for compression seem to work out fairly well. The treated timber is usually about 10 per cent. weaker than the untreated wood.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD AT THE HERIOT-WATT COLLEGE, EDINBURGH, JUNE 7TH, 1919.

MR. ROBERT McLAREN, M.P., PRESIDENT, IN THE CHAIR.

DISCUSSION OF PROF. F. W. HARDWICK'S PAPER ON "THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION."*

Mr. WILLIAM WILLIAMSON (Hamilton): This subject has recently received much attention from various writers in all departments of mining practice and education. To those unconnected with mining, a very likely inference to be drawn from these papers in their appeal for higher education is that the education of those connected with the industry must either have been badly neglected or that it must be of a very low standard. By those acquainted with the management of mines, who know the gigantic preliminary operations required in some mining undertakings, as well as the enormous developments that have taken place in recent years, the very opposite view is likely to be taken.

(*a*) *The Pupilage System.*—In this system a pupil on leaving school is engaged under a colliery manager at a colliery for a certain number of years on payment of a premium. The amount of the premium usually depends on the importance of the colliery and the prospects of securing an appointment at the end of the engagement. In this instance the pupil gains his experience in a sort of first-hand way, which is, theoretically, all right; but what about practical experience? The pupil has been responsible for nothing at all, and has been only an onlooker. At the end of his engagement a pupil may, if he has been a diligent student and attentive to his work, have gained a good theoretical training for future colliery management. On the other hand, so far as practical colliery management is concerned, his training may have been very ineffective and inefficient. There has been no test of his capability in dealing with men, in taking the risks of operations, or in assuming responsibility for the working arrangements in any sphere of underground work. Then there is no final test of the actual capabilities of a pupil at the end of his training, except, of course, the colliery-manager's examination for a certificate of competency. That particular examination, further, may be passed without attendance at any scientific institution whatever. Possessed of his certificate of competency under the Coal Mines Act, and having also a pupilage certificate, the pupil has fulfilled all the requirements necessary for an appointment in colliery management.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 94.

(*b*) *Scientific Training.*—Here the pupil takes a University or other scientific course with a view to obtaining a degree or diploma. In this particular course of training the scientific and the practical are usually combined. On completing his course of scientific training, the student, if necessary, proceeds to the acquirement of whatever practical experience may be required under the Coal Mines Act. Finally, having secured his certificate of competency, he is qualified for any position in mine management.

(*c*) *The Practical Training.*—Here the training is entirely practical in the various departments of underground work. Whatever educational training was obtained was gained through attendance at evening classes as a part-time student at a central scientific institution with organized courses, or by private tuition or correspondence courses. Having completed this course and secured his certificate of competency, the student is qualified for an appointment in connexion with mine management.

After comparing the different methods of training, the pupilage system seems to me to be the easiest and simplest way of qualifying for mine management. It is also, in my opinion, the surest way of gaining appointments and promotion; yet it may be, because of its very simplicity, the most inefficient training of all. It must be admitted that the scientific course is —and the higher the standard, the better—the best course of training for efficient mine management so far as theoretical training goes. At the same time, it must be borne in mind that the University or other scientifically-trained student, even after he has gained his certificate of competency, is, although better-equipped theoretically, at a disadvantage from a practical point of view when compared with a pupilage or a practically-trained student. His practical experience has been acquired in short and somewhat erratic stages, and he cannot be as effective in his practical knowledge as the other type of practically-trained student. At present there is no particular opening for the University or other scientifically-trained student in any special department of mine management. He is obliged to compete with the pupilage class of student for mining appointments. Often he does so with little success because those engaging a manager usually prefer to have someone with practical training and experience. In order to make certain that he fits himself for mine-management appointments in the future, that student finds it necessary to engage upon further practical work in the mine. An alternative course open to him is to pay a premium—perhaps costing him as much as or even more than his University training. Such a student is handicapped, no matter which course he elects to pursue.

From the foregoing observations it is apparent that the outlook or prospect for a scientifically-trained student of any type in mine management is not by any means an enticing one. The great defect, then, in this system of training is the want of practical experience, and a proper method of remedying that defect, without entailing too big a sacrifice on the student already well-trained theoretically, is desirable. This, I think, might be easily accomplished by a short pupilage engagement without premium. Again, it seems to me that the system which combines actual practical experience with attendance at properly-organized mining courses at central institutions, evening classes, or part-time day classes, is superior to the pupilage method. In this way practical experience is gained in every department of underground work. As under officials, these students are placed on their own responsibility, although their work is subject to the supervision of higher officials. They are brought into contact with oft-occurring sudden changes and dangers of actual working conditions underground. They become familiar with the organization of men and the general operations belowground. In this way latent capabilities are developed and training is acquired from every-day experience which cannot be obtained by any other means. In view of these facts concerning the prospects of would-be managers after they have completed their University or other technical training—but possessing, as I have shown, little practical training—it is difficult to understand what is wanted by Prof. Hardwick's "central bureau." It would be very misleading, under present conditions, to give persons unfamiliar with the methods of gaining mining appointments information of courses and methods of obtaining degrees and diplomas in mining on the supposition that certificates are all that are necessary to secure appointments. Any such information could quite easily, I think, be got from the training institutions.

With regard to scholarships, let me say that these may be awarded (*a*) to youths at school willing to extend their studies until they have passed the University or Technical School preliminary examination, or some other equivalent examination, so that they can pass on direct to the University or Technical School courses; (*b*) to those who can pass a certain standard competitive preliminary examination, so as to enter upon the various selected courses of mining instruction; and (*c*) to promising students who have already distinguished themselves in lower educational courses and are desirous of extending their studies. In every case the passing of the preliminary examination for admission to the selected course should be made a condition of entrance, so as to ensure that the students are capable of taking full advantage of the higher instruction. For students retained at day schools beyond the usual leaving age, a maintenance allowance would be necessary, and if they pass the preliminary or other equivalent examination to a University or Technical School and complete, in the first instance, their theoretical training, some organized scheme should be available for them to finish their training in a practical way, while at the same time guaranteeing them remunerative employment. The first part of this training—retention at school beyond school age—is now likely to be provided for by the new education authority. The other organized courses necessary are already in existence, and seem quite sufficient for any demands necessary.

I observe that a special mining certificate has been proposed for agents. That appears to assume a higher training than that necessary for managers, but in what way and to what extent is not stated. In any case, if the agent is to be a responsible manager under the Mines Act he must also have the necessary practical training. Assuming that he has obtained the necessary qualifications, how has he to be promoted? Is he to be promoted by a company over the heads of efficient managers of long experience? In my view the only apparent safe way of employing such a superior and highly-trained mining official is by creating a new mining department capable of utilizing his services. In some recent remarks Dr. Briggs recommends the pupilage system in operation in the East of Scotland, where the company interested is arranging to train sufficient pupils to meet all its future demands for colliery managers. If, however, this particular pupilage system is so very efficient, what is the use of discussing the University or any other system? Dr. Briggs does not give particulars of the premium required for this pupilage or how " the few specials " who are to be admitted are to be selected. Information on these points would be of interest.

With regard to mining apprenticeships, Mr. Dron remarks that " in coal-mining little or no attention is paid to the apprenticeship of those who are to become journeymen colliers or underground workers." Surely this is not in accordance with facts. The usual method of introducing boys into mines is for them to go along with their fathers. If the boys are intended to become hewers of coal, then they are put to work along with their fathers or some other men at the face. Here I think they are trained in the most important branch of mining work.

Mr. A. HANLEY (Sheffield) wrote: We seem to deal with this subject mostly as a scholastic rather than as a mining practice topic. Our first fallacy is to assume a lack of certificated men; our second is to pay them wages or salaries on a low scale; our third is to limit their scope of effort and their jurisdiction, to curtail their initiative, and neglect the talents and knowledge of those who get more than an ordinary smattering of mining knowledge and experience.

If it be granted that a technical course is necessary and that facilities should be given to pitmen of special intellectual inclinations, the schemes and plans advanced by teachers provide material to settle the course of instruction. Then average attention, a good memory, and persistence gains the course. The owner thus possesses a given quantity of mining facts—that is, mental storage, or a supply of material. Training is adaptation and method for the use of these facts, and depends on a variety of circumstances. Training is not a question of the College or the course; it depends on the chief officials giving juniors as much scope, "rope," responsibility, and jurisdiction as possible and on amply appreciating and rewarding their efforts. The cultivation and use of an official's ability and power will depend on the chief officials unburdening themselves and allowing the juniors to get proper training by actual contact with pit operations.

The PRESIDENT (Mr. Robert McLaren, M.P.): I find in looking over Prof. Hardwick's paper reference is made to some twenty-six papers and addresses on the subject. It is quite evident therefore that the question has concerned the minds of a great many people. The training of students for mining is of the utmost importance, and while it is necessary that there should be a good scientific education, it would be, I think, a mistake to neglect the practical side. In my view, it is a mistake to put too much stress on the academic side to the detriment of the practical. One is glad to see that the leading apostle of purely scientific training—Sir Richard Redmayne—took great pains before the Coal Commission to show that he had practical experience. Sir Richard begins to see now that the real test of a mining man's usefulness is primarily his practical knowledge. In view of the many divergent opinions which are held on this subject of mining education, I am going to make a suggestion which I hope will eventually reach the ears of The Institution of Mining Engineers. I think we have now reached the stage when the best plan that can be adopted will be for the

Institution to appoint a representative committee to enquire into the subject from the scientific and practical standpoints. It should be the duty of that committee to draw up and report upon a scheme of education capable of general application throughout the country. The committee ought, I think, to endeavour to focus the views and opinions of all the different districts. In a matter of this kind I am not favourable to an Act of Parliament. If what is decided upon is carried out voluntarily, then I believe the results will be better. An Act of Parliament introduces, as we all know, a spirit of compulsion, and very often penal clauses are attached which are apt to be irksome.

Mr. Sam Mavor (Glasgow): With regard to Mr. Williamson's remarks on the practical aspect of training, and the fact that fathers take their boys into the pits, would it not be possible to do in the pits what is now being done to a considerable extent in the engineering industry, namely, to allocate the most skilled men for the instruction of the boys? The custom hitherto in the engineering industry was to pitchfork apprentices into the shops and leave them to gain such knowledge of their trade as they could. Some who were anxious to learn got on, but others, if they did not happen to be helped along, made little progress. Now, however, in a large number of cases a new system has been introduced. In a turning-shop, for example, the best turner is made "apprentice master." He is removed altogether from the productive side of operations, and his duties consist in going round instructing the boys in regard to cutting speeds, the use of tools, and so forth. Where that scheme has been introduced, the cost involved has been very quickly recovered by reason of the increased productivity of the apprentices. It is quite true, as Mr. Williamson states, that lads go underground with their fathers, but perhaps the fathers are not always the best instructors for their sons in the practical side, as they may not have the faculty of teaching. There is a right and a wrong way of shovelling, a right and a wrong way of holding and using a pick, and a right and a wrong way of setting a prop, and so on. These are elementary points, no doubt, but right through the whole range of miners' work, starting from these elementary points, there is a good deal that might be done in the way of training young miners to become skilled and expert workmen. Could we not have in the pit an intelligent man, corresponding to what is called the "apprentice master" in the engineering industry, whose duty it would be to take charge of the instruction of boys when they begin work underground?

Mr. G. L. Kerr (Glasgow): Does this instructional work apply in the engineering shops after working hours?

Mr. SAM MAVOR: No; it is carried on during working hours. The apprentice master goes round the boys who are engaged on the productive side of the shop's operations, tunes up their cutting speed, sees that their tools are thoroughly in order, and generally makes whatever adjustments are required.

Mr. JAMES COOPER (Edinburgh): I should like to move that it be a recommendation to The Institution of Mining Engineers to arrange for the appointment of a committee to frame a scheme of mining education which might be generally adopted. It seems to me there has been a great deal of talk on this question, and it is really time now we got to business.

The motion was put to the meeting and agreed to unanimously.

The PRESIDENT: I hope that the suggestion made by Mr. Sam Mavor will not be lost sight of by the committee if and when appointed.

The discussion of the paper was closed.

DISCUSSION OF MR. P. A. MOSSAY'S PAPER ON "COOLING OF ELECTRIC MOTORS, WITH SPECIAL REFERENCE TO TOTALLY-ENCLOSED MACHINES."*

The PRESIDENT (Mr. Robert McLaren, M.P.): It is very useful to have the motors cooled in the way described in the paper. I can recall two occasions in Scotland when bad explosions occurred inside motors, although in both instances no one was injured. The heat inside these motors was referred to at the time, and the question was raised whether or not a cooling apparatus might be tried. I am sure that this device will be most useful on all electrical motors and particularly those of the totally-enclosed type.

The discussion of the paper was closed.

DISCUSSION OF MR. J. COOPER'S PAPER ON "AN ELECTRIC HEAD-LAMP."†

Mr. J. BALFOUR SNEDDON (Mid-Calder): The two electric head-lamps I am now exhibiting were in use ten years ago in a Dalmeny shale-mine. They are constructed more or less on similar lines to the lamp described by Mr. Cooper. The second form of the lamp which I exhibit was actually used by the miners themselves. I think we all agree with the author regarding the advantage of a head-light over the ordinary form of safety-lamp. There is no question about this, that a man gets along very much more quickly, more easily, and much more efficiently in his day's work if he has a lamp attached to his cap, and has the free use of his hands at all times. The cable in connexion with the lamps I have here was only an ordinary cable with no protection whatever. In the lamp described by Mr. Cooper the cable is armoured, which is an improvement on the lamps I am exhibiting. As many as twenty of the lamps were regularly in use at one time in conjunction with the Jeffrey-Davis electric boring machine. The lamps were introduced into a closed-light section of the mine, but the use of them was tolerated and not actually approved. The lamps never passed the Government test, and were not, of course, amongst the approved types. Further, no encouragement was given to the manager to extend the use of the lamps. Although the late Lieut.-Colonel C. L. Robinson, Inspector of Mines, was going about the mine, he did not condemn the use of the lamps outright. He tolerated their use only, but the manager had the feeling that in using them he was doing so at his own risk, and that if anything occurred he might find himself in trouble thereby. That has probably some bearing on the remarks already made by our President, namely, that our regulations are sometimes a little cast-iron. If, for example, the Mines Inspector of the district had been vested with some discretionary power to allow the lamp, it possibly would have been continued in use, and most likely by this time it would have been improved even past the stage of the lamp which Mr. Cooper has procured from America.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 103; and vol. lvii., page 53.

† *Ibid.*, vol. lvii., page 58.

Mr. **Sam Mavor** (Glasgow): What was the capacity of the battery and the weight of the lamps?

Mr. J. **Balfour Sneddon**: The capacity was, I think, usually eight hours, but the lamp has been known to keep up an efficient light for ten hours. The weights of the lamps varied a little; the second lamp was rather less in weight than the first.

Mr. G. L. **Kerr** (Glasgow): What is your impression as to how your lamp compares with the one described by Mr. Cooper: do you claim any advantages for your lamp over his?

Mr. J. **Balfour Sneddon**: I do not wish to make any comparison between the two lamps, and, indeed, I am not altogether sure I can express an opinion on that point. I only wished to emphasize the fact that in Scotland we were actually using these electric head-lights ten years ago.

The **President**: It would be most useful to have a lamp of this type carried on the head and used in connexion with rescue work. For many years some of the mines in Scotland have been using the acetylene-lamp, which gives a capital light for all mining operations.

Mr. DAVID PENMAN (Edinburgh): I think Mr. Cooper has done the Institute a good service in bringing to the notice of the members the latest development of the miner's electric lamp. He makes great claims for the head-lamp, most of which are perfectly justifiable. He seems to advocate the use of the electric head-lamp not only as a substitute for oil and electric hand-lamps, but even in mines where naked lights are considered perfectly safe to use. I should like to ask what advantage there would be in scrapping the ordinary spout-lamp and using instead the electric head-lamp? I cannot quite agree with the American statement that from 30 to 55 minutes out of an 8-hour shift are taken up by the miner in adjusting his open-lamp flame. This is certainly not true of the spout-lamp burning oil or tallow. Less than a third of this time should be ample in ordinary circumstances for refills and adjustments.

The lamp described by Mr. Cooper is an American one. Are there no lamps of this type of British design? Does Mr. Cooper consider the design of the lamp perfect? I do not like the length of the flexible connexion from the battery to the lamp, or the method of carrying the cable over the head, a point which has already been commented upon. A certain amount of slack is obviously necessary in order to allow of free movement of the head and shoulders, but the cable ought at least to be strapped to the body, so as to restrict its movements. If worn as shown in the illustration, the cable would be a continual source of trouble in low workings, at the face, and in rescue work. For use with rescue-apparatus the battery could with advantage be supported on the framework holding the apparatus. The outstanding drawback to the electric safety-lamp, as is pointed out by Mr. Cooper, is its inability to detect firedamp. Further, it gives, of course, no indication of the oxygen or carbon-dioxide percentage in the atmosphere. In rescue and recovery operations it is frequently necessary to penetrate into areas where an oil safety-lamp would not burn, and in such circumstances the electric lamp is an indispensable part of the equipment; but in ordinary work the fact that the flame-lamp gives reliable indications of the quality of the air gives it a tremendous advantage over the electric lamp. The firedamp indicator used with the Edison lamp seems, from descriptions I have read, to be a simple and convenient tester, but I should like to see particulars of tests before I could agree that this vital drawback to the electric lamp has been eliminated. Experience of such detectors in the past has not been such as to inspire confidence in their ability to take the place of the oil safety-lamp. Personally, I think that the electric safety-lamp, carried on the head for preference, is destined eventually to displace the oil-lamp in mining; but I do not look for the solution of the gas-detection problem so much in the saddling of the miner or the fireman with a miniature gas-analysis apparatus—although, of course, it always will be necessary to have a means of knowing the state of the air on the spot—as in the organization of a scientific system of proper laboratory analyses which will provide a day-to-day check on the quality of the atmosphere of the mine.

Mr. Sam Mavor (Glasgow): It has always struck an outsider going into a pit, especially an open-lamp pit, that the lighting is not so satisfactory as it might be. I am referring particularly, of course, to the ordinary miner's lamp. I believe it is the case that acetylene-lamps are now being widely used in other countries. I brought a dozen home with me from America some years ago, and I used one myself when going underground. When the men in the different pits I visited heard that these lamps were available, they made application to us for them. I believe we supplied a considerable number of lamps to those who applied for them, but as it was not exactly our business we ceased doing so. The acetylene-lamp is apt, I know, to be a little troublesome, but to those who have an understanding of the care of burners, etc., it is quite a simple arrangement. It certainly gives an immeasurably better light than the ordinary oil-lamp. Could not some alternative to this head-lamp be generally adopted—a more powerful lamp, for example, that could be hung up on a prop? I have seen acetylene-lamps of that type often used on the Continent. It is a lamp about the size of a pint pot, and it gives off a very strong light—about 8 candle-power. In some of the pits on the Continent large numbers of these acetylene-lamps are to be found in use. At one colliery where I inquired into this matter I was informed that during the first few weeks after the lamps were introduced a few of the miners bought them for their own use. They found them to be of so much advantage that in a few months all the miners in the pit —some 800 in all—had obtained the lamps. In safety-lamp pits, under corresponding mining conditions, might there not be a battery with a lamp attached thereto—the lamp being suspended from a nail on a prop? An arrangement of that kind gives a very good light, and it avoids the disadvantage of any possible risk from wire connexions between the battery and the lamp. Incidentally, I may say that in a Japanese colliery where numbers of our three-phase coal-cutters are used the Japanese fitted up in the tool-box of the coal-cutters a head-lamp of 8 candle-power, at each side of the machine, which was, I thought, quite a clever idea. A small transformer was used to reduce the pressure.

Mr. WILLIAM WILLIAMSON (Hamilton): I was surprised a short time ago when some of my students informed me that lamps which they used, and which were burning paraffin-wax, were acting prejudicially on the health of the men. I had never heard of that before.

Mr. J. BALFOUR SNEDDON (Mid-Calder): In the shale district we found that the use of the acetylene-lamp was extending dangerously for our industry. We concentrated on the paraffin-wax, and did what we could to encourage the use of it. We are doing that more and more. At the same time, I rather think that the use of the acetylene-lamp would have been more and more in evidence if it had not been for the intervention of the war. Just previous to the war these acetylene-lamps were becoming rather common. During the war carbide could not be got easily, and that circumstance has rather stopped the use of them. I do not think there is anything at all in the suggestion that the use of paraffin-wax is injurious to the miners' health. A large number of men have been using the paraffin year after year without any harmful effects. There is no question of smoke trouble with the wax—unless, of course, the wax is very dirty. A better light is got from the wax, and there is the added advantage of freedom from smoke.

The PRESIDENT: Acetylene-lamps are used entirely at the lead-mine at Wanlockhead. The lamp in use there is much heavier than the little oil-lamp, and it is not so easily carried on the head. Notwithstanding these drawbacks, the miners would not revert to the old type of lamp, as the acetylene-lamp gives a much better light.

Mr. FRANK MCGINTY (Shettlestone): During sinking operations the electric lamp described by Mr. Cooper would have many advantages over the oil-lamp with tin "shield," commonly called in Scotland a "mistress," as most of the sinkers' work is done while in an upright position. The battery carried at the hip would cause very little inconvenience, and this would be more than compensated for by the certainty of a good light, no matter how much spray might be present in the shaft.

Mr. JAMES COOPER: It is interesting to know that this initiative was shown at Dalmeny some ten years ago, and that the lamps Mr. Sneddon has shown us were in use at that time. The Dalmeny people did not advertise their lamp, so far as I am aware, so that we had to go to America for a lamp of this type.

Mr. SNEDDON: It was improvised on the place by ourselves; it was not manufactured outside.

Mr. **Cooper**: If the lamp had been advertised, the attention of members of the mining community, or perhaps that of the Home Office, might have been drawn to it, and doubtless its advantages over the types then in use would have been recognized.

Mr. Penman appears to question the estimate that is given of the length of time it takes to attend to the adjustment of the open lamp. I believe myself that the time stated—from 35 minutes onwards—is rather exaggerated, but there is no doubt that some time is lost in that particular operation, putting in the wick, and so forth. With regard to what has been said about the design in Scotland of a lamp of that description, I may say that shortly after the last meeting of the Institute in Edinburgh, Mr. John Blake, of Girvan, called upon me and brought with him a very good type of lamp which had been designed at his colliery. In my opinion, the design of the head-piece is better than in the Edison lamp. I have not heard anything more from Mr. Blake on the subject, but I may state that we intend to try one of his lamps when it is completed. Mention has been made of the length of the cable, and there is no doubt that this is a disadvantage to the lamp. The difficulty is that you cannot do without it. The acetylene-lamp, in my own opinion, is a great improvement on the ordinary oil-lamp. I saw these lamps used three years ago in Cumberland for different purposes, and it was generally agreed that they were very much superior to the ordinary oil-lamps, besides being, I believe, much cheaper. On the point raised about higher candle-power, I have found the present low candle-power to be a difficulty in rescue work; a higher candle-power would, for rescue work at all events, be a decided advantage.

Mr. **David Penman**: If you had a mine lighted solely by acetylene-lamps you would need, I fear, a much more rigid system of sampling and analysing the air of the mine.

The **President**: That is perfectly true. The acetylene-lamps could be used with impunity only where there were no bad noxious gases.

The discussion on the paper was closed.

DISCUSSION OF MR. DAVID PENMAN'S "DIGEST OF THE FIRST REPORT OF THE MINE RESCUE-APPARATUS RESEARCH COMMITTEE."*

Mr. **Frederick** P. **Mills** (Newcastle-upon-Tyne) wrote: Rescue-station officials have known from practical experience, ever since the use of breathing-apparatus became compulsory, that the only way the present two-hour types could be safely used was to instruct the wearer to move about very slowly, and to do little or no work. Only when a fatal accident occurred, due to wearing apparatus, did the Home Office think it advisable to investigate the principles of construction and design, and the physiological conditions to be fulfilled by the apparatus. The general conclusion was that the victim had been poisoned by carbon monoxide, and there the matter ended. Further investigation would have shown the reasons why the person was forced to draw poisonous air into the apparatus. Provided the apparatus was airtight, the chief causes would be:—

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 236; and vol. lvii., page 44.

(1) The high percentage of carbon dioxide due to an inefficient purifier.

(2) The high resistance of the purifier causing a negative pressure in the mouthpiece and inhalation and exhalation tubes.

(3) A shortage of oxygen in the breathing-bag.

Even though the apparatus be perfected, the suitability of the person wearing it is of the utmost importance. The wearer may have been carefully examined by a medical man. He may possess all the qualities required of a member of a rescue-brigade, but his stamina may be low. A candidate, before being accepted as a member of a rescue-brigade, should pass an endurance test of not less than equal to walking at the rate of 4 miles an hour.

It is recommended that an Inspector of Mines should be appointed to advise the Home Office on breathing-apparatus in use at rescue-stations and mines. In my opinion, a better way is to be sure that the officers in charge of mine rescue-stations are competent to instruct and to keep apparatus in a high state of efficiency. An inspector such as is suggested in the Report would only see that the apparatus was in usable condition on the day he visited. Carelessness on the part of the person making up the apparatus next day would make it dangerous. I suggest that an examination be held of all persons who are desirous of taking up work in connexion with mine rescue-stations in the same way as the examination for mine managers.

I agree that all apparatus should have official approval in the same way as safety-lamps. In case of accident, a full investigation should be conducted, with a view to finding out the cause and how to eliminate a recurrence of the same. This information should be circulated amongst all rescue-stations.

I was interested in looking over the causes of failure of breathing-apparatus. The failure due to accumulation of carbon dioxide in apparatus was very fully explained by Dr. Haldane in his reports to the Doncaster Research Committee. It is hoped that all rescue-stations have discontinued the use of the helmet type of headdress. I once witnessed a practice where the members of a brigade were all wearing this type of headdress. In a few minutes one of the members fell out, and on examination it was found that, in order to seal the face effectively, the helmet rim had been so tightly pumped with air that it had temporarily stopped the facial arteries. On removing the helmet, the person very soon recovered.

Failure of Oxygen Supply.—In addition to the causes mentioned in the Report, a case has occurred in which the Fleuss twin cylinders have held only half the supply of oxygen at 120 atmospheres. This was due to the tube connecting the cylinder being choked with solder or rust, and only one cylinder was charged. It seems very advisable that, if possible, the oxygen supply should be in one cylinder.

Faulty design of the main valve on oxygen cylinders has always been a source of trouble. Practical experience of various types of valves leads me to suggest that the American valve (Titan) used on the Dræger dress is the most satisfactory. Cases have come to my notice where these valves, although in daily use for five years, have never been interfered with, whilst the valves of other makers constantly needed attention.

With regard to the advocacy of an automatic relief-valve on page 20 of the Report, I am not in favour of such a valve, because there is always the liability of an obstruction getting into it and affecting its efficient working. It is much safer for the wearer to be guided by the behaviour of his breathing-bag, and if it becomes distended so as to be uncomfortable, a relief-valve on somewhat similar lines to the present type (Proto) would be best.

I was interested to see how the Research Committee proposed to get over the question of rust particles in oxygen cylinders. In the Proto apparatus a small gauze is fitted to the reducing-valve in order to prevent the rust from getting into the valve; but if the Committee examine a number of reducing-valves that are in constant use, they will probably find that in many of them the gauze has been eaten away.

The great difficulty with oxygen cylinders is to prevent the accumulation of water inside them, which may be due to the following causes:—

(1) Oxygen is generally saturated with moisture, so that small accumulations of water are found in all oxygen storage cylinders and in small cylinders from this cause.

(2) It is the practice of oxygen-supply firms to test hydraulically, every four years, all cylinders which pass through their hands. Rescue-station officials should see that these cylinders are free from water when returned to them. Several cases have come to my notice where water has been left in

cylinders used with self-contained breathing-apparatus. They have been charged with oxygen in the usual way. The dress has been worn in the training gallery, when suddenly the wearer has found his supply of oxygen has stopped, although the main valve was open. The apparatus has been taken to pieces, and the trouble has been found to be due to water in the reducing-valve. In one case the reducing-valve was only moist, but it had the appearance of having been frozen. On another instance the reducing-valve block was entirely filled with water. On examining the oxygen cylinders, it was found that there was always a possibility of water remaining in the cylinder close to the main valve. Instructions have been given to firms conducting hydraulic tests to the effect that in future after the conclusion of the test the valve should be taken off the cylinder so as to eliminate the possibility of water remaining behind the valve connexion.

(3) The refill pumps which are used for charging small cylinders from large (100 cubic feet) storage cylinders are lubricated in many cases by water. Instances have occurred where water has entered the small cylinders from this cause.

The purity of the oxygen used is of considerable importance. There is no doubt that the necessity for meeting the demand for oxygen for processes in connexion with the European war has conduced to lowering the standard of purity of the oxygen. In one instance I know of, the supply contained only 50 per cent. of oxygen. An analysis of oxygen should accompany each supply cylinder.

I wish to correct the Report where it is stated that half-masks are employed at the Durham and Northumberland Collieries Rescue-stations. It was found out that the face-masks were very unsatisfactory, because of the great difficulty in fitting the wearer's face. After experimenting, the half-mask was abandoned in the year 1914 in favour of the mouthpiece, which has given satisfaction.

I notice that no mention has been made of the nose-clip dangers, although I understand that steps have been taken to provide a nose-clip which is not easily knocked off.

In a letter to the *Colliery Guardian* I suggested an improvement in the headdress of self-contained breathing-apparatus, as follows:—

At Newdigate Colliery on October 8th, 1916, an accident occurred to a man wearing a self-contained breathing-apparatus (oxygen type). It was suggested at the time that the mouthpiece used with the apparatus was not satisfactory, inasmuch as it was shown that when wearing a mouthpiece it would be quite easy for a man, by dropping the lower jaw, to break the joint between his mouth and the mouthpiece. Further, that these mouthpieces might be used satisfactorily for a million times or more, and then a wearer might forget himself, becoming interested in exploration work, etc., and indulging in too much "rescue conversation." He would thus be liable to breathe the outside atmosphere, and if this were poisonous, the ultimate result would be collapse. It has also been said that, in the event of a man being unconscious whilst wearing a self-contained breathing-apparatus, there would be a tendency to drop the lower jaw and inhale the outside atmosphere.

In order to get over this difficulty, a suggestion was made to add to the mouthpiece a chin-strap so as to prevent the lower jaw from dropping.

The next accident was at the Minnie Pit, North Staffordshire, where it was brought out in evidence that the nose-clip was continually being knocked off the wearer's nose; in fact, it was further stated that several of the members of the brigade were overcome. Doubtless this was due to the nose-clips being knocked off and also to too much "rescue conversation."

The goggles worn by men wearing self-contained breathing-apparatus have not been a success. There is always the liability of irritant gases getting between the goggles and the face, due to the different shaped faces.

A way in which to overcome the liability of accidents of this kind occurring is possible. Many persons will have seen and inspected the latest gas-masks used by the army. Have they ever tried fitting the face-mask part, which contains goggles and nose-clip, on to the mouthpiece of self-contained breathing-apparatus of the liquid-air and oxygen types? I have tried one, and am of the opinion that the face is effectively sealed against the outside atmosphere. The wearer holds the mouthpiece exactly as on the apparatus used at present. The mask is so made that the goggles attached to it can be wiped in the event of any steam getting on them. The nose-clip attached to the inside of the mask is used exactly as at present. As far as my experiments go, the gas-mask seals off the face effectively from the outside atmosphere, and even if the nose-clip or the mouthpiece came off, no outside atmosphere would be breathed.*

The Report also mentions that the Durham and Northumberland Collieries Rescue-stations encourage suggestions from members of the staff; and it must be admitted that useful information has been obtained by this means.

Minor accidents to men in training at a rescue-station should be carefully investigated by the officer in charge, and to prevent a recurrence a report should be issued to each official.

In looking through a list of minor accidents which have taken place in rescue-station practice, I thought a useful purpose would be served in enumerating them, as under:—

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* See "Improvement in the Headdress of Breathing-apparatus," by Frederick P. Mills, *Colliery Guardian*, March 8th, 1918, vol. cxv., page 494.

(1) Man had to come out of the gallery due to his nose-clip continually falling off.

(2) Due to leakage at main oxygen supply pipe. This is not uncommon in the Fleuss dress, in which a knock on the reducing-valve block may loosen its connexion with the cylinders. If the connexions were made with a left-hand instead of a right-hand screw, this might be prevented; in fact, a knock wound tend to tighten the joint.

(3) Man came out of gallery owing to the too frequent use of the bye-pass. I do not agree that the bye-pass should be so constructed that there is no check on the supply taken into the bag. A wearer has been known on several occasions to lose all his oxygen through turning on the bye-pass; in fact, the sudden release of pressure is likely to damage the wearer, and in some cases the mouthpiece has been blown out of the mouth.

(4) The air-supply was cut off due to a kink in the oxygen supply pipe.

(5) The front of the breathing-bag, although comparatively new, was crumpled to bits, owing to deterioration of the india-rubber.

(6) Due to the values in the inhalation and exhalation tubes sticking.

(7) The main oxygen supply being cut off, due to the neglect of fitting a safety chain, or of forgetting to turn on the oxygen supply before connecting up the mouthpiece to the wearer.

(8) Case where a man had taken intoxicating liquor. It appeared that although only a small amount had been taken, because of the coldness of the weather, the effect was to make the man excitable when in the training gallery.

(9) Breathing fumes due to indulging in too much "rescue conversation."

(10) Case of man vomiting in his mouthpiece.

(11) Case of a man inhaling fumes on removing his mouthpiece to cough.

I should like to mention more about case No. 5, where the breathing-bag dropped to pieces, due to deterioration of the rubber. In the Home Office Regulations, collieries are required to keep either two self-contained breathing-apparatus or two smoke-helmets. In Northumberland and Durham the owners recommended the smoke-helmet, because it was always safe in the hands of a novice and did not deteriorate in the same way as a self-contained apparatus.

With regard to Part III. of the Report, I am in complete agreement with the recommendation respecting the age limit of men suitable for mine-rescue work, so far as the workmen are concerned. Occasionally men of 50 years of age come forward, who from their appearance might be taken to be ten years younger. It would appear from this that such men could be safely included in a colliery rescue-team. I should like to know whether it would be possible to define by means of tests, using the cycle ergometer, if the standard of these men was suitable for rescue-work.

There is another point with regard to age limit about which it would be interesting to learn what the Research Committee have to say. It becomes necessary to recover work for occasional inspections to be made. Any regulations enforced ought to be made sufficiently elastic to allow inspection work being carried out by competent mining engineers, wearing rescue-apparatus, who might be over the age limit allowed for men doing manual work, in order that inspection may be made before the roadways are so disturbed as to render useful scientific observation impossible.

The Report deals very fully with the training of colliery rescue-brigades, and I was interested in the scheme proposed by Mr. Stevenson. The weakness of this scheme would appear to be that the men would work for two masters. In Durham and Northumberland the members of the colliery and permanent brigades are taught the use of fire appliances, both for surface and underground fires.

I agree that the uniform code of ventilating signs should be adopted, but do not agree that any useful purpose would be served by forwarding all the colliery tracings made in compliance with General Regulations 142 (*b*) to the rescue-stations. A few typical plans should be kept, but as a general practice I do not think that the results that would accrue would be in proportion to the trouble taken.

I was pleased to see that the Research Committee recommend competition between rescue-brigades, also that Sir William Garforth has gone further in offering a shield for competition. This is just what is required to encourage men to come forward for training in the work. In America, a great deal of useful competitive work goes on in this direction.

With regard to an annual conference of instructors, I think it would be desirable to everyone that a conference should be called to discuss many of the points raised in the Report, and that this should be done before any new legislation is made on the recommendations of the Research Committee.

The investigations as to the finding of defects and the ultimate prescribing of a form or forms of apparatus suitable for rescue work were stopped at the outbreak of the war in August, 1914; but since then apparatus using oxygen and liquid air have been used in somewhat similar forms by the various belligerents. I believe that valuable information in this direction could be obtained from the army, and also from the Royal Air Force.

The Royal Air Force used both oxygen and liquid air to supply oxygen to airmen when flying at high altitudes. As it was absolutely necessary that apparatus should be light in construction, the present oxygen cylinders are superseded by a much lighter one made of special steel. The substitution of these cylinders for the ones now in use would decrease the weight of oxygen self-contained apparatus by at least 25 per cent. Further, a better method of controlling the evaporation of liquid air from liquid-air containers and vessels was devised.

There is no doubt in my mind that the result of the Research Committee will embody all the good points of the present-day apparatus.

In conclusion, I strongly endorse Lieut.-Colonel Logan's remarks on the importance of discipline in connexion with rescue-brigade work, but I disagree with him on the necessity of appointing a number of Mines Inspectors to inspect appliances at collieries. It would be better to attach to each central rescue-station competent men whose ability in rescue work at collieries in conjunction with the fire protection of collieries has been determined by examination. These men would, amongst other duties, visit collieries to inspect and report upon periodically the condition of rescue and fire appliances.

Mr. G. L. BROWN (Mansfield) wrote: Rescue work in mines may be classified under four heads, namely, apparatus, training, organization, and men. Wearers of apparatus may have their lives endangered through a defective apparatus, a loose system of training, weak organization, or by a rash action by a member of a team. This remark applies equally to ordinary pit practices. Those in charge of rescue-stations have at all times to guard against any one of the above-mentioned causes.

The Digest of the Report shows that the Committee have gone very thoroughly into the subject, and a broader basis has been outlined for the conduct of rescue-operations. Before a conference of instructors and others is convened, more information concerning liquid air and its application to rescue-apparatus should be given. Too much is being said about oxygen apparatus, while the faults of the liquid-air type are not discussed. An apparatus which permits the wearer to work moderately hard, without overworking it, for three hours if necessary, should receive every attention. It is the simplest, and more than half of the controversial points connected with oxygen apparatus are non-existent.

Testing for leakages of oxygen by immersion in water will be too often omitted, and unless all the unions are severely shaken while immersed the test may be worthless. The mere pushing at a joint may produce a leakage. The wet-meter does not appear to be reliable for fixing the oxygen feed. With two similar meters I have found a negative error of 0·3 litre per minute in the summer, when compared with a tested float-meter. With such a meter the minimum of 2 litres, suggested as an enforcement, would be enroached upon without the instructor being aware of the fact. Owing to the wearing of the bobbin, float-meters are also liable to inaccuracies. Correct meters are as important as correct pressure-gauges. They should be calibrated annually at the National Physical Laboratory in addition to being subjected to periodic displacement tests with oxygen.

The composition of rescue-teams working under actual conditions determines the system of training. The leader of every brigade should be conversant with the mine workings as far as possible, and in every case of exploration work the captain should have a tracing. The Report (Appendix I., 3 and 6) mentions an exception. I know of an instance where this exception was permitted, and, but for the prompt entry of the reserve team, the outcome of which might have been disastrous. The second man in the team should be captain, followed by other members with whom he always practises, and the team completed by the inclusion of a member of a resident brigade, who is best placed midway between the captain and the vice-captain in the rear. It is a fallacy to expect even three teams of permanent men to continue for extended periods without calling upon neighbouring colliery teams for help. When there is a shortage of men in the earlier stages, five, consisting of resident-brigade men, form the teams, and similarly five colliery men form the teams which follow on. On a sufficient number of the latter coming to hand, one resident-brigade man can be included in each team, thus forming teams of six men, which become better balanced for extended operations. The co-operation of resident-brigade and colliery men should be encouraged. Where resident men are not available, the first teams are generally mixed ones.

The captain is responsible for his team, and he should receive special instruction in the care and maintenance of rescue-appliances and in organization. The advantages of this instruction are apparent. Further, a fully-trained member of the rescue-corps placed in the centre of a team enables him to keep a watch on all the apparatus. His presence inspires confidence. At a recent disaster this system was carried out satisfactorily.

As a rule, colliery men prefer pit practices, which can be made more interesting and more realistic than in the gallery. An observant instructor can usually detect misuse of the apparatus by mixing with the team. The instructor should accompany the team in order to impart knowledge, so that fouling of the pit-workings would hinder beneficial instruction. The weaker parts of the apparatus are found out at pit practices due to the extra wear and tear. Pit practices for both colliery and permanent-corps rescue-men, and special instruction for captains, have been in operation in the Nottinghamshire and Derbyshire Coalfields for some time, and have added considerable interest to the training. Two station and two pit practices are given annually, and, in addition, the captains attend at the station for a whole day every six months. The rescue-stations at Mansfield, Chesterfield, and Ilkeston are under one control, and this greatly assists the possibilities of the above scheme. There is great advantage in having uniformity of apparatus and organization in any coalfield or adjacent coalfields. Each station, however, works for an independent area, and while in one area there is a pit practice, there are teams training at the other stations.

A member of a permanent corps accompanies his instructor to the pit practice and practises with the colliery team. On the same day a captain of a team from another colliery attends the station and maintains the strength of the staff. He assists in the care, testing, and assembling of the appliances generally, and also on the return of the practice sets from the pit. In the event of a disaster at a colliery, the members of the rescue-team or teams would act as leaders only. A large colliery may have two teams, thus providing sufficient leaders for ten or twelve teams in the event of extended operations.

Mr. Stevenson's scheme is interesting, but it does not provide any additional advantage in meeting the demands for continuous work by the permanent corps. It will be difficult to ensure that more than five men are immediately available (men who are resting) except during night-time. For continuous rescue work, always working with a reserve team, it is absolutely necessary to call in the neighbouring colliery brigades. Members of resident brigades must be thoroughly fit and ready for extended operations at any moment. They have to set and keep the ball rolling until the colliery brigades arrive. When not so employed, they can be kept fit easily by regular morning exercises, in addition to the ordinary routine at the station and the pits.

Station practices might be conveniently increased to four per annum, making six with two pit practices. Colliery men rather forget information regarding constructional details than how to wear the apparatus. The two additional station attendances might be usefully utilized for assembling apparatus, stretcher work, demonstration with revivers, smoke-helmets, and fire and other appliances. This detailed instruction would prepare them for any competitions, which would stimulate and improve the general efficiency of the men. Rescue-brigade competitions could conveniently consist of an oral examination on rescue-appliances, practical examination on testing, preparation and adjustment of the apparatus, revivers, brigade formation, and lastly a spell of, say, three-quarters of an hour in the smoke gallery for elimination contests, with one-and-a-half hours for the final tests.

Mr. GEORGE WELSH (Coatbridge): The feeling I have is that the whole Report could be put into a very few words. The Research Committee have taken about two years to discover matters that practical men associated with rescue work would never have suggested or recommended at all. The suggested method to be followed in testing the apparatus is one that would never have been made by practical men experienced in the work. If, as is suggested, the straps have to be removed, so that the water test may be carried out as recommended, it means that 2 litres of fixed supply has to be arrived at. In July, 1917, Dr. Haldane, Dr. Briggs, and Mr. William Walker were at the rescue-station at Coatbridge, and a man was put into the fresh air with the apparatus and made to walk at the rate of 4 or 5 miles an hour on 2·75 litres of oxygen, and he really needed it all for what he was doing. The conclusion I came to after seeing that test was that there was nothing on the market that will satisfy these recommendations. Certain recommendations and suggestions have been made by scientific men who have no experience of the practical side of the question.

Mr. JAMES COOPER (Edinburgh): On February 15th, 1919, our brigade in Edinburgh was called out to a spontaneous-combustion fire. We were using the Meco apparatus, and we submitted it before use to the water test, as recommended. We put the machine in as it stood, and, so far as the Meco is concerned, no connexions had to be undone or interfered with. As a result of the test, two new tubes I had in one machine showed small leaks. We rejected that one, and another machine also showed a leak. It is only fair to say that what might be an easy operation for one machine might be more inconvenient to carry out with another.

Mr. WELSH: I am referring to the Proto apparatus. It is suggested in the Committee's Report that the canvas straps should be removed as a preliminary to the water test. If these straps be removed, the position is that before they can be replaced again the joints of the apparatus have to be undone.

Mr. COOPER: I would not remove the straps. I would put the machine into the water as it stood. We did that constantly for three days at the spontaneous-combustion fire to which I have referred.

Mr. J. BALFOUR SNEDDON: Is there any practical objection to the Proto being dipped in water as it stands, as is done with the Meco apparatus?

Mr. WELSH: The objection is that it would be a big and difficult task to carry out at a colliery. A waterproof canvas bag would have to be filled full of water.

The further discussion of the paper was adjourned.

THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,

Held at the University College, Nottingham, May 24th, 1919.

Mr. H. EUSTACE MITTON, President, in the Chair.

Mr. H. Eustace Mitton was re-elected President for the ensuing year.

REPORT OF THE COAL INDUSTRY COMMISSION, 1919.

By H. EUSTACE MITTON.

The Report of the Coal Industry Commission, 1919, as accepted by the Cabinet, states, among other things, that upon the evidence already given the present system of ownership and working in the coal industry stands condemned, and that some other system must be substituted for it, either nationalization or a method of unification by national purchase and/or by joint control.

I feel that the members of the Institution should have an opportunity of answering the charge found by the Commission, which reflects on every mining engineer in the country, and ask that before proceeding with the ordinary business of the meeting consideration be given to this matter.

Under Clause 9 the Commission state that on evidence already given the working in the coal industry stands condemned.

Who are the parties responsible for condemning the system of working in the coal industry? We find they comprised gentlemen who by their profession are not mining engineers, and whose opinion therefore must be based on the evidence submitted, without the aid of any technical knowledge of the subject. The Coal Commission Bill was introduced into the House of Commons on February 28th, 1919, and provided (Clause 5) that the Commissioners should, as soon as practicable, make an interim report on the question of wages and hours of miners. The Prime Minister stated that Sir John Sankey was prepared to guarantee that a report would be given to the

Government on March 20th, 1919. He was asked if the report would be on these two points, and he replied: "Yes, only on these two points."

It is important to consider the terms of reference for the evidence asked for by the Commission. In a letter from the Secretary of the Commission to the coal-owners' and miners' associations he states:—

> "I am directed by the Chairman of the Commissioners to inform you that he desires your Association to send one witness to give evidence before the Commissioners on the first part of their Inquiry, which it is intended to conclude by March 20th. That part of the Inquiry will be confined to a preliminary investigation of the questions of wages and hours. I should make it clear in the first instance that what you are now being asked to do is merely to provide evidence of a preliminary character, and that a further opportunity will be accorded to you in the later stages of the Inquiry to supplement that evidence and to deal with matters which are not immediately germane to this part of the Inquiry."

As one of the committee representing the coal-owners of this district, I may state that the evidence was prepared on the lines asked for.

The evidence produced and accepted by the Commission from the men covered a much wider area, and was principally directed to the question of nationalization of the mines, which, as indicated in the above reference, was never intended to be the subject of this hurried and rapid enquiry.

The important point is that the Commission have advised the Government and found that the present system of conducting the largest industry in this country is wrong, and have recommended certain courses to be adopted for improving the system.

In considering the Report we find that immediate action is recommended under nine heads. It is assumed that the reason for this urgent course is that there must be a deplorable condition existing in this great industry for such drastic recommendations, and we shall do well to consider them seriatim.

(1) *Housing.*—The very brief evidence given on this important question showed that in certain districts the accommodation is bad. Now, what is the true position? We have just passed through a great war, and the coal-mining districts are suffering from lack of proper accommodation such as is inevitable. In this country we have district councils whose duty is to see that proper and adequate houses are erected for the people. No industry in this country pays greater attention to the housing of its employees than the coal-mining industry. We have only to look at the new villages erected by the coal-owners in this district and others, and we see evidence on all sides of the great care and thought expended by the employer in seeing that suitable and good houses are erected for the employee.

Because there are some cases of bad housing, that is no reason why the mining engineering of the past should stand condemned, and it cannot be under this heading that such a sweeping resolution can be found.

(2) *Baths at the Pit-head.*—In this district, where the miners travel by train to and from their work, they would not use baths at the pit-head. Only those who have visited the Continent, and know the system there, can give an opinion on this subject. It would be interesting to know whether the learned Chairman, and the three gentlemen who have appended their names to the Report, condemning the mining system, have visited and seen the conditions of the baths as used abroad.

(3) *Clearance.*—This is one of the matters in which there is room for work to be done, and the prospect of increasing production by giving greater attention to underground clearance is well worth following up. There are various ways in which this important matter can be given greater attention, but it is quite evident from the large number of collieries turning good outputs that on this point the Commission cannot have found that the present system of mining stands condemned.

(4, 5, and 6) *Transport, Reduction of Voluntary Absenteeism, and Use of Machinery.*—A slight increase of production might be obtained by attention to the first point; the fact of the steady working of the collieries shows that very little can be expected from this source.

With regard to voluntary absenteeism, the Miners' Federation jointly with the coal-owners appealed to the men during the past few years, when the country wanted all the assistance possible, and it is known what effect the appeal had, and no improvement can be looked for in this direction.

Machinery in mines seems to have strongly impressed the four gentlemen, and all those who know the mining conditions of to-day can well imagine how easily the man who does not understand the subject can be misled on this point. There will not be a large increase; in fact, it is doubtful whether there will be any increase at all in this district by the further installation of machinery. The introduction of machinery underground has made rapid strides in past years, and there is as much prospect of increasing the production by the introduction of coal-cutters and conveyors as there is of widening shafts or of putting up upcast pits for winding coal when the area of coal to be won has only a short life left.

It is probable that this unit influenced the finding of the Commission that the present system of mining stands condemned. If this is so, then it is a terrible calamity for the country that persons who do not understand what the introduction of machinery means should have given a wrong verdict, with the very serious result which will inevitably follow.

(7 and 8) *Pooling of Wagons and Elimination of Unnecessary Distribution Costs.*—The first unit has been thoroughly considered during the past few years, and much done to reduce the idle life of the wagon. The different types of wagons make this a more complicated question than some imagine.

Elimination of unnecessary costs is desirable in the same way that it is desirable that all unnecessary work should not be done.

(9) *Uniformity of Accounting.*—No objection can be raised to this, but it will not increase the production, although doubtless it would be beneficial for purposes of comparison.

(15) Under this clause the Commission advocates that "the colliery worker shall in the future have an effective voice in the direction of the mine." Mr. Hodges, who was a member of the Commission, stated emphatically in addressing a witness that labour was going to have a larger share of its products than in the past.

The reason for the establishment of local pit committees and joint district committees is that matters can be discussed and investigated by the management, and the men are certainly desirous of having such committees and are worthy of every encouragement from the mining engineer. The larger share, as advocated and emphasized by Mr. Hodges, should meet with the full support of the mining engineer where labour exerts itself to improve and maintain the product of its hand.

The greatest industry of this country has been built up by private individuals, and the advancement of mining has gone forward by leaps and bounds. The output has been increased from 59 million tons to 287 million tons per annum in a little over half a century. Millions of pounds have been lost by private individuals in attempting to prove and develop difficult and unremunerative areas, and now that this great industry is picked out for censure and on the scrappiest evidence, in a hurried sitting, with the deliberate instructions to the coal-owners not to consider any evidence except on hours and wages, while the open door is allowed to the men to place before the Commission any statement they desired on any subject they wished, the finding by four men is:—

> "Even upon the evidence already given, the present system of ownership and working in the coal industry stands condemned, and some other system must be substituted for it, either nationalization or a method of unification by national purchase and/or by joint control."

On behalf of the members of this Institution, I now beg to move the following resolution:—

> "That this meeting desires respectfully to call the attention of the Prime Minister to the following facts:—

"(1) That the Coal Commission Act, 1919, provided that the Commission should on or before March 20th, 1919, make an interim report on the question of wages and hours of the colliery workers, and that the Prime Minister gave an undertaking that this point, and only this point, should be the subject of the enquiry up to March 20th. This undertaking was confirmed by the Terms of Reference from the Secretary of the Commission on February 27th, 1919, giving directions that the evidence should be confined to matters of wages and hours.

"(2) That in spite of the undertaking and the Terms of Reference, evidence was taken from the Government witness and the men's witnesses on the present system of individual ownership of collieries. No evidence was put forward from the owners' side, as they were debarred by the Terms of Reference from tendering such evidence, and so confined themselves entirely to the limits laid down, and to the undertaking given by the Prime Minister.

"(3) It is further pointed out that no evidence was heard from the consumers, who are, of course, vitally affected by the finding.

"(4) In view of the above facts, we, the Midland Counties Institution of Engineers, respectfully submit that it is contrary to the principles of justice that the finding of the Commission, as set forth in paragraph 9, should stand without evidence being heard on behalf of the owners and those who are now working and carrying on collieries, which evidence has been excluded by the express direction of the Commission and the undertaking given by the Prime Minister.

"And that a copy of this resolution be forwarded to the Prime Minister and to the Secretary of The Institution of Mining Engineers."

Mr. G. A. Longden (Draycott): One of the most important points, in my opinion, is that no evidence was heard from the general public, and surely they are the people who will feel the effects of nationalization more than any one else. The railway companies since they have been under Government control have treated us very badly in the matter of supplying us with empty wagons, so that it is impossible for us to keep up our usual output. The Government have put their thumbs on the railways, and the railway people have ceased to take any interest; it is not unreasonable, therefore, to presume that there will be the same effect if the Government take over the collieries.

Mr. W. Price Abell (Derby): I agree thoroughly with the resolution proposed by the President, and have very great pleasure in seconding it. As Mr. Longden has pointed out, it is not only mining engineers, but the public as a whole, who are dependent upon cheap power. Coal-mining is the biggest industry in the country apart from agriculture, and now under the stress caused by the war a section of the community on whom the success of the country has largely been built up is being held up for condemnation without being afforded the opportunity of saying anything on the scientific and practical side as to the effects likely to result from the proposals put forward. We are anxious to see the prosperity of this great industry maintained for the benefit of the general public, and it should go forth that we protest strongly against the one-sided evidence on which the recommendations of the Coal Commission purport to be based.

Mr. George Spencer (West Hallam): I should like to emphasize the point that not only did the coal-owners not give evidence against nationalization, but that they were not afforded the opportunity of giving evidence on the subject at all—neither was the public. It amounts to this: the owners loyally abided by the Terms of Reference and the other side did not.

Mr. B. McLaren (Pye Hill): I think that some notice ought to be taken of a statement which was made at the second enquiry, but possibly it may be thought better that it should form the subject of a separate resolution. I refer to the statement of Mr. Sidney Webb that the owners, including the colliery managers, found it cheaper to have accidents than to make provision against them. No body of men could have interested themselves more in the prevention of accidents than the colliery managers of this country. The North of England Institute of Mining and Mechanical Engineers, and the other Mining Institutions established after it, have all been formed for the very purpose of enabling them to carry on our mines safely, and we ought this afternoon to pass a resolution of strong protest against that unfounded and unjust remark of Mr. Sidney Webb.

The President (Mr. H. Eustace Mitton): While I fully sympathize with the feelings expressed by Mr. McLaren, I want to point out that this resolution deals with the finding of the Commission which sat up to March 20th. Mr. Sidney Webb's remark was made during the sitting of the present Commission, and I should like to confine our resolution to what occurred at the previous one.

Mr. R. Blunt (Woodville): Could it not be pointed out that in our opinion the Commission, in making a recommendation with regard to nationalization in their interim report, had exceeded their powers? It would then be a much stronger resolution than the present wording.

The President's resolution, in the form given above, was then put to the meeting and carried unanimously.

The President: With reference to Mr. McLaren's protest against a remark made by Mr. Sidney Webb, inferring that colliery managers find it cheaper to kill and maim men than to provide means for their safety, I should like to point out that various members have already protested at the Commission, but unfortunately their protests have not appeared in the press. I was present when Mr. Sidney Webb was taken to task severely, and the only way in which he attempted to defend himself was to confess that he did not mean what he said. That was, of course, a very lame excuse, but considering the source from which the suggestion emanated, and the little effect it had upon the members of the Commission, do you think it is worth our while to bother any more about it?

A **Member** suggested that the very fact which the President had mentioned—that no reference to Mr. Sidney Webb being taken to task had appeared in the press—made it desirable that the Institution should take steps to let the general public know, through the press, how unfounded such a suggestion was.

The **President**: May I suggest that perhaps Mr. McLaren's object might be attained if such a protest were published in the local papers as the protest of this Institution. I will look up the exact words which were used, and, if you wish it, such a communication shall be prepared and sent to the press.

Mr. B. McLaren: If you will do that, it will meet the object I have in view.

Mr. G. Spencer: I should like to point out that the very aims and objects of every Mining Institute are the preservation of life, the advancement of mining, and the improvement of the conditions of the workers. The remark of Mr. Sidney Webb was a slur on the Charter of The Institution of Mining Engineers.

It was eventually agreed to adopt the President's suggestion and to send a communication to the local papers protesting against Mr. Sidney Webb's statement.

THE NOTTINGHAMSHIRE COALFIELD.

BY H. EUSTACE MITTON.

The extension in the east of Nottinghamshire of the hidden coalfield has in recent years been further proved by borings conducted by the Butterley Company, Limited, the Stanton Ironworks, Limited, and other companies, and by sinkings conducted by the Bolsover Company. The findings of the above companies are of great value, and throw further light on this interesting subject. The boreholes dealt with in this paper are as follows:—

Farnsfield No. 1 (Fig. 1, Plate V.).—This borehole was put down a little to the north of Farnsfield Station, the height above Ordnance Datum being 225 feet 4 inches. The boring commenced on February 4th, 1914, and was finished on November 15th, 1914. The diameter of the hole was 13 inches at the commencement and 4 inches at the finish. The total depth bored was 1,556 feet 8 inches (see Section *a*, Fig. 2, Plate V.).

The findings of this hole proved the bottom of the Bunter Beds at a depth of 481 feet. The breccia was proved at 714 feet 4 inches, and underlying the breccia a thickness of marl of 472 feet, including the Newcastle group of strata. The Coal-Measures proper were reached at a depth of 1,186 feet 4 inches (the base of the Etruria Marls). The first marine bed was reached at a depth of 1,530 feet 8 inches, and no further strata of any interest were proved.

The method of boring was by the percussive system to a depth of 101 feet, and then by shot-crown to the end. The water-level in the hole rose to 60 feet from the surface, and maintained this level throughout the boring.

Farnsfield No 2 (Fig. 1, Plate V.).—This borehole is situated a little to the South of Farnsfield Station at Car Bank Farm, the height above Ordance Datum being 183 feet 7 inches.

The boring commenced on January 7th, 1915, and was finished on January 27th, 1916. The diameter of the hole at the commencement was 19 inches and at the finish 5 inches, the total depth bored being 2,600 feet (see Section *b*, Fig. 2, Plate V.).

The findings proved the base of the Bunter Beds at a depth of 404 feet, the breccia at 637 feet 5 inches, and below the breccia a thickness of Marl of 599 feet 3 inches, including the

Newcastle group of strata. The Coal-Measures proper were reached at a depth of 1,236 feet 8 inches.

The first marine bed was proved at a depth of 1,524 feet 5 inches, the Mansfield marine bed at 1,800 feet 9 inches, and the Top Hard Seam, estimated at 2 feet thick, at 2,302½ feet.

This seam was proved during the night, and a very unsatisfactory bore was made of the same. During the remainder of the boring various other thin seams were proved, but it is extremely difficult to locate any seam definitely. The water rose in the hole to the surface when 470 feet had been bored, and a feeder estimated at 3 gallons per minute continued to flow from the same.

The method of boring was by the percussive system to a depth of 523 feet, and then by shot-crown to the end.

Farnsfield No. 3 (Fig. 1, Plate V.).—This borehole was put down at Allesford Lane, Farnsfield, about 2 miles south-east of No. 2 hole, the height above Ordnance Datum being 140 feet 8 inches. The boring commenced on April 16th, 1917, and was finished on March 9th, 1918. The diameter of the hole at the commencement was 19 inches and at the finish 5½ inches, the total depth bored being 2,957½ feet (see Section *c*, Fig. 2, Plate V.).

The findings of this hole proved the depth to the breccia to be 720 feet 9 inches, the thickness of marl underlying the breccia, including the Newcastle group of strata, to be 672 feet 3 inches, and the Coal-Measures proper at a depth of 1,393 feet.

The first marine bed was reached at a depth of 1,659 feet 2 inches, and the Mansfield marine bed at a depth of 1,918½ feet.

A seam of coal, assumed to be the Top Hard, was proved at 2,294½ feet, and only gave a section of 14 inches. No other seams of any account were proved in the boring, but a few thin seams were passed through, varying from 3 to about 12 inches thick. A feeder of gas was met with at a depth of 2,427 feet from the surface. This was followed by a feeder of briny water, with some oil indications.

The boring was carried out by the percussive system to a depth of 625 feet; shot-crown was then used to a depth of 1,978 feet 10 inches, diamond-crown boring to 2,510 feet 11 inches, and shot-crown boring to 2,957½ feet.

The strata proved at this hole corollated very well with No. 2 hole at Farnsfield, showing a thickening in the ground overlying the coal and thinning in the seams. No indication of serious faulting was discovered in either hole.

Ollerton (Fig. 1, Plate V.).—A borehole has been put down half-a-mile to the north of Ollerton Church by the Butterley Company,' Limited, and the Stanton Ironworks, Limited, jointly. The position of this borehole is shown on the plan (Fig. 1, Plate V.), the height above Ordnance Datum being 134 feet 9 inches.

The boring was commenced on June 26th, 1918, and was finished on January 30th, 1919. The diameter of the hole at the commencement was 16 inches and at the finish 6 inches, the total depth bored being 2,279 feet 11 inches (see Section *d*, Fig. 2, Plate V.).

The findings of the boring are as follows:—The base of the Bunter Beds was proved at a depth of 425 feet, the breccia at 877 feet 10 inches, and below the breccia a thickness of marl of 66 feet 8 inches. The Coal-Measures proper were reached at 944½ feet, the base of the Permian at 877 feet 10 inches, and the base of the marl at 944½ feet.

No discovery was made of the first marine bed, but a marine bed which was a very good sample was proved at a depth of 1,017 feet 2 inches, and acknowledged by the geologists to be the Mansfield marine bed.

A seam of coal, which gave a good section over 5 feet thick and contained good hard and bright coal, was proved at 1,553 feet 9 inches, and appears to be the Top Hard. The Dunsil and Waterloo Seams were proved afterwards, and at 2,185 feet 1 inch a seam of coal was proved about 5 feet thick, which gave a good section of bright coal with hard coal at the bottom, and was estimated to be the Deep Soft Seam, the small hard coal-seams underlying this seam having come up into the Main Seam. Three other small seams were then passed through, and at a depth of 2,278 feet 11 inches a seam of coal was proved about 2 feet 4 inches thick, which was assumed to be the Deep Hard. This seam appears to have split, as another seam overlying it about 12 feet above seems to be part of the original Deep Hard Seam.

A feeder of strong briny water was met with at a depth of 897 feet 8 inches, and this continued to flow at the rate of about 50 gallons per hour over the top of the borehole until the finish.

Boring operations are now being conducted by the Butterley and Stanton Companies jointly at a place called Boughton, which is about 3 miles to the east of Ollerton.

Retford Boring (Fig. 1, Plate V.).—This borehole is situated at Hayton Smeathe, about 2 miles north-east of Retford Church, the height above Ordnance Datum being 30 feet. The boring commenced on August 29th, 1918, and at the time of writing is in the Coal-Measures at a depth of 1,568 feet. The diameter of the hole at the commencement of boring was 17 inches, and at the present time is 8 inches.

The method of boring adopted was by the percussive system to a depth of 953 feet 3 inches, and at the present time the hole is being continued with shot-crown.

The water-level at the hole stood at 22 feet from the top until a depth of 1,450 feet was reached, and then a spring was met with. The water now runs over the top of the hole at the rate of 4 gallons per minute.

There is no indication at the present moment as to what measures the present boring is in, beyond the fact that they are Coal-Measures, but the next few hundred feet should prove very interesting (see Section *e*, Fig. 2, Plate V.).

Costs.—A table giving particulars and the cost of carrying out the boring operations conducted at the various holes is given below:—

FARNSFIELD No. 1.

Total depth bored	**1,556 feet 8 inches.**
Date commenced	**February 4th, 1914.**
Date finished	**November 15th, 1914.**
Total cost	**£1,969 3s. 2d.**

FARNSFIELD No. 2.

Total depth bored	**2,600 feet.**
Date commenced	**January 7th, 1915.**
Date finished	**January 27th, 1916.**
Total cost	**£5,029 13s. 8d.**

FARNSFIELD No. 3.

Total depth bored	**2,957½ feet.**
Date commenced	**April 16th, 1917.**
Date finished	**March 9th, 1918.**
Total cost	**£5,575 2s. 9d.**

OLLERTON.

Total depth bored	**2,279 feet 11 inches.**
Date commenced	**June 26th, 1918.**
Date finished	**January 30th, 1919.**
Total cost	**£5,347 4s. 10d.**

RETFORD.

Total depth bored	**1,568 feet.**
Date commenced	**August 29th, 1918.**
Boring still in progress.	——
Cost to date (April 26th, 1919)	**£2,276 5s. 3d.**

These costs are those incidental to the boring, and do not include any legal charges or lease costs in connexion with the undertaking.

Much valuable information has been acquired from the records obtained from the borings described above, and a remarkable alteration in the formation of the ground is revealed. As shown on Fig. 1 (Plate V.), it will be seen that the Top Hard Seam has been proved, and is being worked at Rufford Colliery at a depth of 551 yards, and at Newstead Colliery at 490 yards. The Farnsfield boreholes show that the Coal-Measures lie at a very much greater depth at the short distance from Rufford and Newstead, and from the records as given in the *Memoirs* of the Geological Survey the Top Hard Seam at Oxton

(Section *f*, Fig. 2, Plate V.) appears to be at a depth between what has been proved by the sinking at Newstead and the boring at Farnsfield.

The indications from the above borings are that the New Red Sandstone thickens in an easterly direction, and that at some point east of Crown Farm the Coal-Measures commence to rise. It is probable that the upper seams are cut out or come within close proximity to the New Red Sandstone east of Ollerton.

The above theory would be considerably upset by the presence of faults, and it is not at all improbable that a large fault exists, running in a south-easterly direction through the parish of Kirklington. There is probably another fault running in a west-to-east direction between Rufford and Farnsfield.

An interesting point is the fact that the Top Hard Seam at Kirkby Colliery, which lies between Mansfield and Newstead, and is north-west of Oxton, is found to be thinning as it goes to the east. At the present time there is a section of 3 feet 1 inch, excluding the Coombe Coal to the east of Kirkby Village. Another important finding in the boring results is that at the Farnsfield and Ollerton bores the Coombe Coal appears to lie almost on top of the Main Seam; if there is any parting between the two, it is of so small a character that it is hardly noticeable. At Kirkby Colliery on the east side the Coombe Coal has a thickness of about 16 inches and lies some 10½ inches above the Main Seam. The records published by the Geological Survey relating to the boring at Oxton show that there was no distinct parting between the Coombe and the Main Seam, and the section of 4 foot 1 inch, as given for this seam, appears to refer to the Top Hard, including the Coombe Coal.

The further development and advance of workings at Rufford Colliery, together with the development of the Ollerton and other coalfields in this neighbourhood, will doubtless throw further light on this very interesting subject. At the present time, judging from the results obtained from the borings in the east, a short description of which has been given in this paper, there is no doubt that a very difficult problem confronts the mining world with regard to the value of the seam to the east of Rufford and Ollerton, and a considerable amount of money will have to be spent in further research-work before anything can be expended on the developments of areas in this direction.

Owing to the thickness of the water-bearing strata, the capital required for the sinking and opening-out of the seams in this district is very heavy, and before any large sum is spent it will be well worth further research, and the gradual proving of the strata in an easterly direction from the points which have already been proved.

The **PRESIDENT**: I should like to add that since I prepared the notes which I have just submitted, those who were responsible for the borings and who had first intimated to me their desire to go ahead have, owing to the findings of the Sankey Commission, now altered their intention, and decided that they will not proceed further until the Government have come to some definite decision with regard to the future, so that the whole of this great work in the development of the east of this county is being held up on account of the attitude of the Government to-day towards the mining industry of this country.

Mr. **G. A. LONGDEN** (Draycott): I have some particulars with regard to three boreholes (Kirklington, Bilsthorpe, and Wellow) which might be of interest to this Institution, but there is hardly time to go into them this afternoon. I think that this easterly development is well worth the serious consideration of our members, and, in order that this may be given to it, I move that the discussion on Mr. Mitton's paper be adjourned until our next meeting.

The **PRESIDENT**: I have been indebted to Mr. Longden for much valuable information in the preparation of my notes, and if he could supply some of the facts in his possession, then, if it be decided to adjourn the discussion, he can submit his paper and the whole subject can be discussed together.

Mr. **LONGDEN**: I should be very glad to do that. I should like, in the meantime, the Institution to obtain information regarding their results from the engineers in charge of the Kelham, Bevercotes, and South Leverton borings, in order that we may discuss the whole subject. I feel sure that such a discussion will be very advantageous to our members.

Mr. **T. G. LEES** (Newstead Colliery): I think that this paper is one of the most important we have had for many years, and that it is very desirable that every opportunity should be afforded for a full discussion. We have made up our minds to sink at Newstead, and I have been trying to get information at all the different points, but up to the present time we have not obtained all that we should like. It is very essential that we should take into consideration all the other borings at the same time, and discuss the whole coalfield.

Mr. **GEORGE SPENCER** (West Hallam): The subject of the paper is of prime importance at the present time, and if we can persuade Mr. Longden to give us a supplement to the President's paper, it is essential that we should have further opportunity for discussing it.

The discussion of the paper was accordingly adjourned.

DISCUSSION OF PROF. F. W. HARDWICK'S PAPER ON "THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION."*

The PRESIDENT (Mr. H. Eustace Mitton): It is essential that the young man who elects to enter the profession should have, in the first instance, an opportunity of studying the practical side of the subject, in order that he may apply his mind to the life that he has chosen and understand the objects of his study.

The system adopted in the past has proved how successful it has been by the rapid strides made in the greatest industry in this country, and a great opportunity is now before the coal-owners of furthering the efforts of the rising generation by assisting in giving facilities for increased study of the subject through the Universities now established in the large towns.

The course of training, in my opinion, should be one where the student should first of all be able to study at the mine the practical working of the mine, coupled with attendance afterwards at the University, where he can attend lectures and receive a full training in the profession he has chosen.

A young man should realize that if he is really intent on taking up the mining profession, with the object eventually of becoming a certificated colliery manager, he must be prepared for a proper and full period of study with the sacrifice of time and money which the same entails.

No young man should, if he is able to do so, enter the profession until he has received the necessary education to enable him to take his place in the office with those with whom he comes into daily contact.

The best starting place for any young man is in the surveyor's department, where he not only receives the education which this department affords, but becomes familiar with the pit and its workings through studying the plans and attending the underground surveys.

Great opportunities are afforded young men during this part of their career by coming into contact with the officials of the various departments, from whom much information can be acquired when attending to the working of the mine.

At the present time, the system in force is for a young man to commence at the age of about 15 and to go through the various departments at the collieries, as follows:—(1) mine-surveying, (2) electrical engineering, (3) mechanical engineering, and (4) practical work at the mine.

During his apprenticeship he may attend the classes at one of the neighbouring Universities and often the evening classes in science and art departments in the villages.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 94.

It is important that a better opportunity should be afforded the young men to attend at the Universities, and it seems to me that the best system is for a young man to start at the colliery, and, after six months' work at the mines, to take a course during the winter at the University, followed by a further course at the mines, so as to mingle his studies with the practical work at the mine and the theoretical work at the Universities during the time when he is serving his articles or apprenticeship at the collieries.

In order that this course may be properly carried out, financial assistance is required to enable the University to have Mining Departments fitted up with a proper and efficient staff and with adequate instruments, and it rests with the coal-owners to assist in this direction and to see that material is provided so that proper instruction can be given to those who desire to take this course.

It is for the young man himself to sacrifice time and money during the period when he is undergoing his studies, and if the necessary financial assistance can be found there is no doubt great use can be made of the Universities in all large towns, so that a proper and efficient staff may be raised for the purpose of training the future generation of mining engineers on a very much more elaborate scale than in the past. I therefore move the following resolution:—

"That the Members of the Midland Counties Institution of Engineers, having considered the paper by Prof. F. W. Hardwick on the training of Mining Students, advise that it is very desirable that greater use should be made of the Universities of our large towns in the coalfields, and that the coalowners of the country be approached to contribute funds on such a scale that the Mining Departments in these Universities can be fitted up in the manner suitable for the training of the mining engineers in the district."

Mr. T. G. LEES (Newstead Colliery): I can endorse the greater part of what has been said by the President. I also agree with that part of the resolution as to the desirability of the coal-owners contributing to the fitting up of Mining Departments in the Universities; but are we not rather premature in taking up this question at the present time, seeing the strong views taken by the men as to the way in which mine-managers should be brought up? They have got the idea that colliery managers in all cases must be brought up at the face, and have been actually engaged in getting the coal. They seem to overlook altogether the question of scientific training. Their whole talk is that a man must get coal, do gang work, set props, and be employed at the pit-bottom before he can take charge of a mine. That is starting at the wrong end. A manager ought, of course, to have practical mining experience, but he can obtain that by means of the "sandwich" system, as Mr. Mitton suggests. The point has been discussed as to the advisability of contributing anything until we know what is going to take place—who are going to be the owners, and who are going to manage the mines. We can, however, pass the resolution as it stands, with the hope and the belief that we may be able to hold our own in the future.

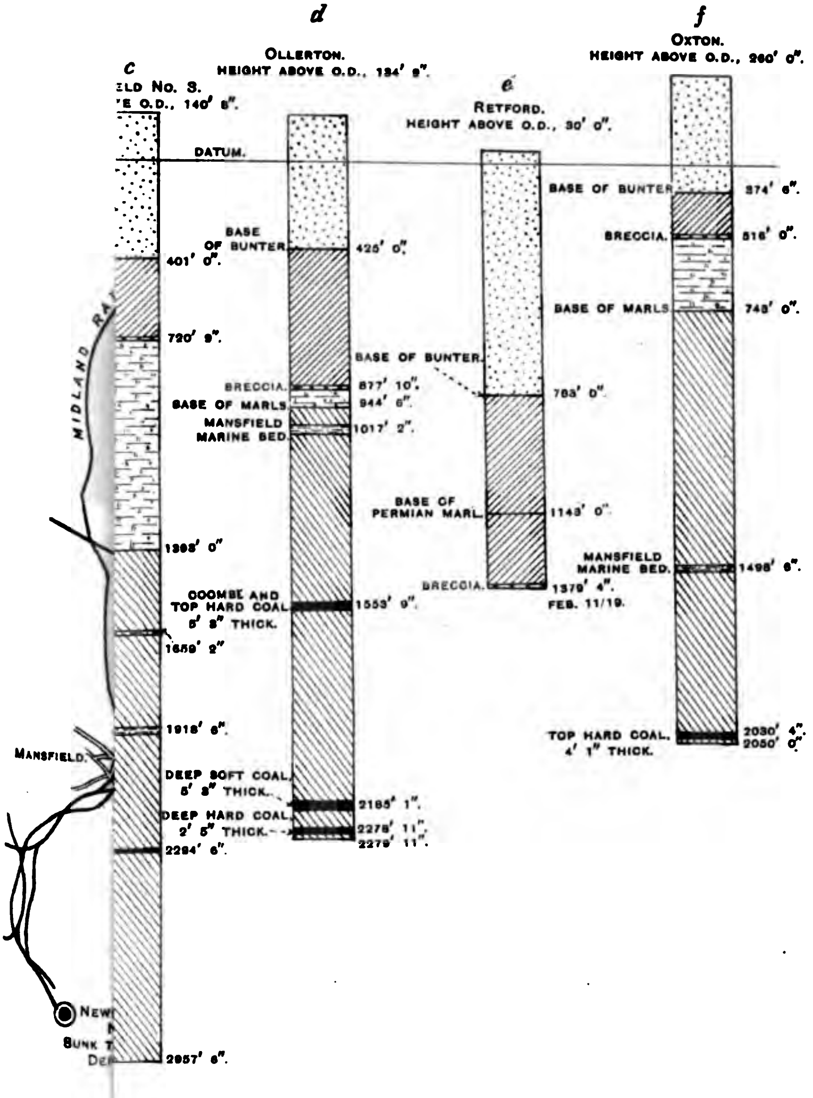
Mr. GEORGE SPENCER (West Hallam): I heartily support the resolution, notwithstanding the difficulties confronting us which Mr. Lees has outlined. Whatever the future of our mines may be, it is very necessary that a manager should be a practical man, but that does not imply that he should be an expert setter of pit-props, expert as a coal-face worker, and expert in driving headings, and in every other kind of pit work. He may not have the physical power to do all or any of the these particular kinds of work, but he may be, in every sense, a capable judge of the work done, and whether it be good, bad, or indifferent. I quite agree that the first stage in the course of training of any mining pupil should be at the pit. He should first of all become familiar with every object at the mine both above and below ground and have opportunities of seeing actual work carried out, so that when he afterwards attends the mining classes he can follow the instructor more intelligently. In other words, he ought first to know something of the objects about which he goes to receive instruction, for it is impossible for him to understand properly what is described unless he has seen the things themselves. I am not in favour of a long term at the pit and a long term at the College or class. In six months a student is apt to lose touch with the actual work going on, and I think a shorter period would be more desirable. The ideal system would be one in which a student worked at the mine in the daytime and was instructed the same day or shortly afterwards in the principles underlying his work; but, of course, few have the physical power to carry out that course with advantage. The next question is how short the period should be to enable him to acquire a theoretical knowledge—or rather, I would prefer to say, a knowledge of the principles which govern the work of mining? It is of primary importance that the mining pupil should have received a good education, and have a fair knowledge of physics, mathematics, chemistry, and subjects of that kind. A mining engineer has to know more than a little of a great many subjects, and must specialize in a few. I quite agree that the best results are likely to be obtained from the "sandwich" system, but I do contend that the period should be as short as is practicable.

Mr. W. PRICE ABELL (Derby): The whole trend of this discussion seems to have been the "sandwich" system—that is, the linking-up of the theoretical studies with the practical work.

The theoretical man has been under a cloud because he has merely studied his theory and not seen it applied in practice; he has been learning principles, but not the application of them. Forty years ago we went to night science classes—the only classes available at the time—and had to take in the theory of our studies as well as we could. The " sandwich " system has gradually developed, so that it has become almost universal at the present time. I think the more we can enable the people who get University degrees in this subject to extend their studies into the coalfield itself the better, instead of becoming mining engineers with a University degree without having even seen a coalfield. It is the association of theory with practice which will better enable one to earn one's living as a mining engineer. To try to teach the theory of swimming without water is no worse than to try to teach the theory of colliery work without a colliery. At the present time the Government are trying to make mining engineers in six months. They are recruiting officers to whom they are offering a course with the idea that at the end of it they can get good appointments. If they would realize that there is a large number who have gone through several years of hard work and study who are unable at the present time to obtain appointments, they ought to recognise the futility of expecting that men who undergo a course of half-a-year can step straight away into a good post. It might be wise for the Institution to draw the attention of the Government to the way in which these men are likely to be disappointed.

The President: My only object is to get something before the Council at their next meeting, and I do not think you need fear, if you accept the resolution, that anything will be done until the question is decided as to what the future of collieries is really going to be.

—Sections of Boreholes.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E O.D., 140' 8".
d
Ollerton.
Height above O.D., 134' 9".
e
Retford.
Height above O.D., 30' 0".
f
Oxton.
Height above O.D., 260' 0".
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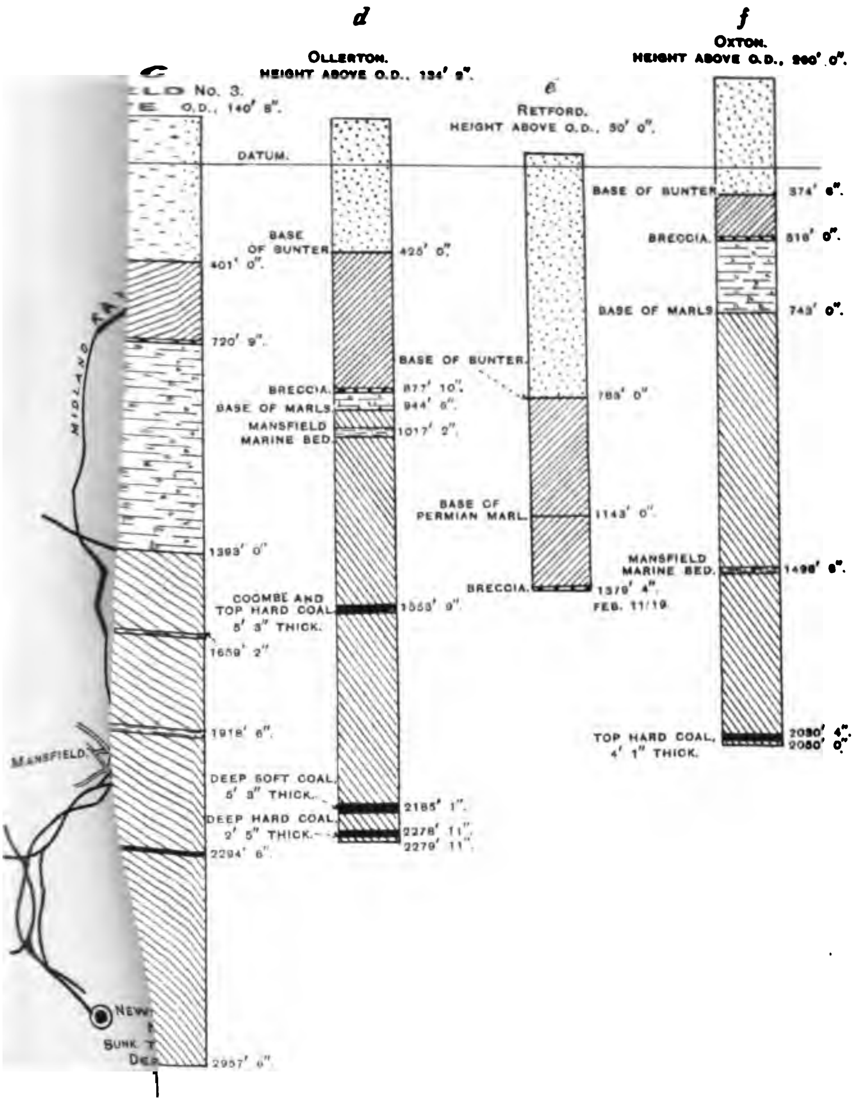
Base of Marls.
944' 6".
Mansfield Marine Bed.
1017' 2".
Coombe and Top Hard Coal, 5' 8" thick.
1553' 9".
Deep Soft Coal, 5' 8" thick.
2185' 1".
Deep Hard Coal, 2' 5" thick.
2278' 11".
2279' 11".
Base of Bunter.
783' 0".
Base of Permian Marl.
1143' 0".
Breccia.
1379' 4".
Feb. 11/19.
Base of Bunter.
374' 6".
Breccia.
516' 0".
Base of Marls.
748' 0".
Mansfield Marine Bed.
1498' 6".
Top Hard Coal, 4' 1" thick.
2030' 4".
2050' 0".

Vertical Scale 600 Feet to 1 Inch.

—Sections of Boreholes.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401' 0".
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1918' 6".
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d
Ollerton.
Height above O.D., 134' 9".
BASE OF BUNTER
425' 0".
BRECCIA.
877' 10".
BASE OF MARLS.
944' 5".
MANSFIELD MARINE BED.
1017' 2".
COOMBE AND TOP HARD COAL 5' 3" THICK.
1553' 9".
DEEP SOFT COAL, 5' 3" THICK.
2185' 1".
DEEP HARD COAL, 2' 5" THICK.
2278' 11".
2279' 11".
e
Retford.
Height above O.D., 50' 0".
BASE OF BUNTER.
788' 0"
BASE OF PERMIAN MARL.
1143' 0".
BRECCIA.
1379' 4".
FEB. 11/19.
f
Oxton.
Height above O.D., 260' 0".
BASE OF BUNTER.
374' 6".
BRECCIA.
519' 0".
BASE OF MARLS.
743' 0".
MANSFIELD MARINE BED.
1498' 6".
TOP HARD COAL, 4' 1" THICK.
2080' 4".
2080' 0".

Vertical Scale 600 Feet to 1 Inch.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,
HELD AT THE CENTRAL SCHOOL OF SCIENCE AND TECHNOLOGY, STOKE-ON-TRENT,
JULY 21ST, 1919.

MR. J. R. L. ALLOTT, VICE-PRESIDENT, IN THE CHAIR.

FUEL ECONOMY IN THE PRODUCTION OF POWER AT THE APEDALE WORKS OF THE MIDLAND COAL, COKE, & IRON COMPANY, LIMITED, APEDALE, NEWCASTLE, STAFFORDSHIRE.

BY WILLIAM HILL AND J. A. CORK.

At the present time the subject of consolidating the generation of electrical power in super power-stations is engaging the attention of the Government, the engineering world, and the general public. We think, therefore, that it may be of timely interest to place on record our experience in the development of, and such results obtained from, a comparatively small installation, as they seem to point in the direction of a better utilization of the large available supplies of fuel in the form of surplus gases from the coking and blast-furnace plants of the country. These gases are now, in the majority of cases, being utilized somewhat indifferently, but after suitable preparation they are undoubtedly a valuable source of fuel for internal-combustion engines. To the extent such fuel is available, it would minimize the need for such drastic changes as those contemplated, and would provide an economical source of power for the industrial and domestic life of the country.

During the past few years many interesting and valuable papers have been read before various Institutes and scientific societies giving, amongst other things, comparisons as to the thermal efficiency of the alternative methods of using this class of fuel and estimations of the probable volumes of the same that are available. For this reason it was not considered necessary to the object of this paper to restate these figures, but rather to confine our remarks to a description of what, from experience, we have found to be necessary to ensure simple, reliable, and efficient service from such fuel.

About the year 1905, it was decided to investigate closely the question of the fuel-consumption of the various steam plants in commission at the works with which we are associated, as there appeared to be indications that fuel values would be considerably and perhaps permanently higher in the future, owing to mining legislation, deeper mining, higher material and maintenance costs, shorter working hours, etc. During these investigations tests were taken as to (1) calorific value of the fuel consumed; (2) feed-water temperatures; (3) evaporation of the Lancashire and cylindrical types of boilers in use under ordinary conditions; (4) radiation and other losses in steam-mains, etc.; (5) steam-consumption of the various sizes and types of engines, which consisted of slide-valve throttling type non-condensing, automatic expansion, non-condensing, simple condensing, and winding- and hauling-engines fitted with hand-controlled expansion-gear; (6) the number of hours during which the separate units were in actual service; (7) the number of hours during which the steam-mains, etc., of the separate units were under pressure but not under load; and (8) the actual duty derived from the various units. The results obtained were tabulated and each unit of plant was debited with the heat losses, etc., between the plant and the boilers, when it was found that (1) the feed-water temperatures varied from 120° to 180° Fahr.; (2) the average evaporation of the boilers, taken over a period of a week at each of the boiler plants, varied from 2·1 to 4·6 pounds of water per pound of fuel consumed (the fuel consisted of small coal, refuse from the coal-screens, and smudge from the coal-washery); (3) the steam-consumption, including radiation losses, etc., varied from 35·72 to 68·5 pounds per brake-horsepower-hour; (4) the actual load-factor of the units was low (the steam-mains varied in length from a few feet up to 700 yards, distributing saturated steam at pressures varying from 50 to 100 pounds per square inch); and (5) the overall thermal efficiency averaged 2·26 per cent.

These investigations proved conclusively that there was room for considerable improvement, despite the fact that the equipment was, on the whole, in good working condition and equal to what was considered at that date to be adequate.

At that time the question of replacing the obsolete bee-hive coke-ovens in use with bye-product ovens was under consideration, and it was ultimately decided to install the regenerator type, with plant to recover the first products, namely, tar, ammonia, and benzol, to manufacture sulphate of ammonia, to undertake the distillation of tar, and to use the surplus gas in internal-combustion engines for the generation of electric power on comprehensive lines for the works generally.

The question of the type and size of the power unit and the method of the installation of the same were considered at length, and from inspections and enquiries made it was found that the general practice was for such plants to be supplied with partly-cleaned and purified gas at varying pressures and heating values, and to be placed under the control of attendants without specialized training or experience.

The plant was installed under conditions which we considered necessary to ensure reliable and efficient service, and, with this object in view, special attention was given to (*a*) gas purification, (*b*) the regular heating value of the gas, (*c*) constant pressure of the gas at the engine stop-valves, (*d*) the provision of circulating-water at a constant pressure and free from impurities, with reasonable storage provided for cases of emergency, and (*e*) means to enable the foregoing conditions to be automatic, so as to reduce as far as practicable the personal element in the control of the plant, and to render the supervision no more exacting than in a steam-driven station. The foregoing conditions were provided for as follows:—

(*a*) The surplus gas from the coking plant, after passing through the bye-product recovery plant, flows through an automatic pressure-valve *A* (Fig. 1, Plate VI.) designed to close if the pressure on the surplus gas-main should fall below a predetermined figure. The discharge side of this valve is coupled to the suction mains of the motor-driven positive-displacement rotary gas-boosters *B* and *B*1, which are designed to raise the pressure of the gas to suit the varying resistance of the purifiers *C*1, *C*2, and *C*3, with provision for adding two extra purifiers later. The purifiers are of adequate size to pass the maximum volume of gas required and to reduce the sulphuretted hydrogen from 600 to 50 grains per 100 cubic feet, and are arranged to reverse the rotation of the gas as follows:—

(1) Either 5 "on" in rotation, any one first.
(2) do. 4 do. and 1 "off" do. do.
(3) do. 3 do. do. 2 do. do. do.
(4) do. 2 do. do. 3 do. do. do.
(5) do. 1 do. do. 4 do. —

An average of the tests taken over a long period was 48 grains per 100 cubic feet.

(*b* and *c*) A suitable size of gas-holder *D* is installed to mix thoroughly the gas of varying heating values, and to discharge at a regular value and constant pressure to the engine supply mains. A recording calorimeter indicates any change in the heating value of the gas as supplied to the engines, and a gas-meter measures the gas-consumption of the station. An average analysis of the gas as supplied to the station is as follows:—

	Per cent.
Carbon dioxide (CO_2)	3·60
Carbon monoxide (CO)	8·50
Oxygen (O_2)	0·40
Unsaturated hydrocarbons (C_nH_m)	2·00
Hydrogen (H_2)	44·60
Methane (CH_4)	21·40
Nitrogen (N_2)	19·50

British thermal units, 415 per cubic foot net.

(*d*) Motor-driven pumps *E*1 and *E*2 (Fig. 1, Plate VI.) common to any power units are provided, and are so arranged as to deliver the water into a storage tank *F* placed at a suitable height to give the requisite static head to the circulating-water system of the engines The water-treating plant *G* is installed to remove the hardness due to carbonates, and means are provided to add an excess of carbon dioxide from the burnt gases from the engine exhausts in order to reduce the liability of encrustation from hardness due to the presence of sulphates.

(*e*) An automatic valve *H* for controlling the varying gas-consumption is installed between the suction and discharge mains of the gas-boosters, and is actuated through the pipe *I* by a pressure control-valve *J* operated by the gas-holder.

These arrangements enable the power units to run under varying loads and conditions with the gas- and air-valves in the full open position without attention from the attendants, and reduce the risks that generally accrue from pre-ignition, etc. The pistons and valves and other internal parts are free from carbon or other deposits, and no signs of corrosion are apparent. The supply of circulating-water is reliable. Efficient means are provided for recording the heat-consumption of the station. Considerable attention was given to the question of deciding the type and the size of the power unit necessary to enable the plant to operate at a reasonably high load-factor, under the varying power requirements of the collieries and ironworks load, and it was ultimately decided to install high-speed vertical eight-cylinder four-crank units of 600 brake-horsepower direct-coupled to three-phase 550-volt 25-period alternators. The first two units were put into service during the autumn of 1911, and it was early demonstrated that:—

(1) The design of the governing gear and the gas and distribution systems required modification; (2) means must be provided (owing to the high percentage of hydrogen present in the gas) to retard the speed of combustion of the fuel charges; and (3) provision must be made for removing any accumulations of oil-vapours, etc., from the closed crank-cases of the engines. These difficulties were overcome by (1) dividing the gas- and air-governing and the distribution into two sections; (2) adding a portion of the products of combustion from the engine exhausts (after cooling) to the fuel mixtures; and (3) arranging for

induced ventilation of the crank-cases by a specially-designed system which automatically creates the necessary conditions from the products of combustion as they escape into the atmosphere.

The plant was then put into service, and the results were such that an additional set was brought into use early in 1913. These sets gave continuous service, as required, free from involuntary stops and interruptions to supply, and over 5,000,000 units per year were distributed up to August, 1914, with an average load-factor of 0·727 and an average overall thermal station efficiency of 20·13 per cent.

For purposes of comparison it may be stated that the thermal efficiency of generation in respect of 421 steam-driven central power-stations for the year ended March, 1918 (according to a statement made by Mr. D. Wilson, Technical Adviser to the Controller of Coal Mines), is 8·5 per cent. and the coal-consumption 7·3 million tons. Of these stations, forty supply half the electrical energy of the country, with a thermal efficiency of 11·5 per cent. The remaining 381 stations had an average thermal efficiency of 6·8 per cent.

It may be observed that particulars of the generating costs of the plants under review are not stated; the reason for this is that such costs are necessarily affected by many factors peculiar to the different districts; but the results will bear comparison with those expected from the large stations proposed or with any published records we have seen.

The results from August, 1914, to the present time have been up to the same standard, except for the higher costs which have arisen from the abnormal conditions during this period.

During the year 1918 an additional power unit was added to meet increasing demands. The station and equipment are designed to accommodate seven gas-driven units, or a total of 4,200 brake-horsepower; and from careful tests taken as to the volume of surplus gas available from the coking plant of eighty-two ovens, a reasonable surplus over the requirements of the complete equipment is assured.

Continuous records are taken of the volume of gas used in the station and its calorific value. All distribution circuits are fitted with integrating wattmeters, and from these records and the labour, stores, etc., charges, the working results are obtained.

During the year 1913 the question of providing blowing plant to meet the increasing requirements of the blast-furnace plant was considered at length, and from the results obtained with the gas sets in the station using surplus gas from the coking plant hereinafter called No. 1 Power Station, it was decided to install units of a similar type and capacity, and to provide for additional power units.

Station No. 2 (Fig. 2, Plate VI.) is designed and equipped for three blowing sets (two of which are installed), each of a capacity of 12,500 cubic feet of free air compressed up to 8 pounds per square inch as a normal duty and with a reduced volume at 10 pounds per square inch. Each set consists of one four-crank eight-cylinder vertical enclosed engine arranged to govern at various speeds from 200 to 300 revolutions per minute, as required, coupled direct to a three-crank vertical enclosed forced-lubrication air-compressor fitted with piston-valves; and three generating sets (one of which is installed) similar to those in No. 1 Station.

The use of blast-furnace gas is, of course, an entirely different proposition from that of coke-oven gas, and, as in the use of the former, it was necessary to give special attention to (1) gas-cleaning, cooling, and constant pressure, (2) lubrication, (3) circulating-water, and (4) automatic control of the plant.

Gas-Cleaning.—At the point where it was proposed to connect the plant to the crude gas-mains, the average composition and condition of the gas was as follows:—

Pressure	0 to 8 inches of water-gauge.
Temperature	650° Fahr.
Dust content	6 grammes per cubic metre.
Carbon dioxide	6·19 per cent.
Carbon monoxide	26·97 „
Hydrogen	1·30 „
Nitrogen	65·54 „
British thermal units per cubic foot net ...	95.

After consideration of the information gained whilst investigating various plants in use in this country and on the Continent, we decided to install an Halberg-Beth dry-cleaning plant consisting of seven units, with special auto-valve *A* (Fig. 2, Plate VI.) to protect the plant from explosions which might arise owing to ignition from other sources; an auto-valve *B* to control the pressure of the cleaned gas in the supply-main to the engines on a variable consumption; and a final gas-cooler *C* and driers *D*1 and *D*2 to remove moisture in suspension. From daily continuous tests taken, the following represent the average results obtained from the plant:—

Pressure	3 inches of water-gauge constant.
Temperature	80° Fahr.
Dust content	0·0021 gramme per cubic metre.
Carbon dioxide	9·17 per cent.
Carbon monoxide	26·41 „
Hydrogen	2·03 „
Nitrogen	62·39 „
British thermal units per cubic foot net ...	96.

It is not considered necessary to give here a detailed description of the gas-cleaning plant, as it has already been the subject of several excellent papers.

Lubrication.—With the object of improving the crank-case oil-consumption and of keeping the oil in good condition and ensuring a reliable supply, a central oiling system is installed, consisting of duplicate motor-driven turbine pumps *E*1 and *E*2 (Fig. 2, Plate VI.), to raise the oil to the storage tank *F*. This tank has a capacity equal to one hour's requirements, and is fixed at a suitable height to give a static head of 12 pounds per square inch at the engine bearings. A low-level storage and filter-tank *G* is installed in the basement, to which the oil from the engine crank-cases is drained. Air-coolers *H* are provided for keeping the oil at a temperature of about 30° Fahr. above the atmosphere.

Circulating-water.—Similar plant to that installed at the No. 1 Station is provided.

Automatic Control of Plant.—The supply of gas as to pressure and mixture, and circulating-water and oil as to quantity and pressure, is fixed, the engines running with all valves in the full open position and without adjustment when dealing with all loads met with in regular service.

Recorders operated electrically from a synchrome time system are installed to give 60 days' records as to pressure of the crude and the clean gas, oil, water, and air, and the calorific value of the gas entering the engines.

The complete plant was put into service early in 1915, and during the last four years has given continuous service free from involuntary interruptions. The plant is shut down periodically for 2½ hours at intervals of from two to three months for internal examination of the gas-cleaning apparatus. The load-factor and running costs of the sets compare favourably with those of No. 1. Station. The sets have been in service for an average of 149 hours per week during the period mentioned.

The generating set runs in parallel with the sets in the No. 1 Station (which is situated at a distance of about 1,000 yards), on a variable load, and contributes to a reliable source of power for the whole of the works. The supply of surplus gas at this plant is sufficient for a total output of about 8,000 brake-horsepower, which equals for both plants upwards of 12,000 brake-horsepower.

The main portion of the plant was supplied by the following manufacturers:—Coke-oven gas-cleaning and storage plant, Messrs. C. & W. Walker; blast-furnace gas-cleaning plant, Messrs. Fraser & Chalmers; gas-engines, The National Gas Engine Company, Limited; electrical equipment, The General Electric Company, Limited.

Distribution of Power.—During the electrification of the existing plant and the installation of new plant many varied and interesting problems were presented. The equipment consists of upwards of 100 motors, varying in size from 1½ up to 250 brake-horsepower, with a total brake-horsepower of 3,800, which amount is being constantly increased. These motors drive the ventilating plants, air-compressors, main, endless, reversible endless, and main-and-tail haulages, winding- and pumping-engines, coal-cutting machines, face-conveyors, coal-washers, screens, gas fans and exhausters, coal-elevating, and coke-oven charging and discharging plant, etc. The lighting load is upwards of 120 kilowatts. When the electrification scheme is complete, the distribution will extend over an area of 7 to 8 miles at various voltages from 2,500 to 110. Two mines are run entirely from the power plants, no other power supply being available.

In conclusion, we may add that it would seem from our experience that the thermal efficiency and consequent fuel economy of power plants using surplus gas from the coke-ovens and blast-furnaces of the country would compare favourably with what is expected from the proposed super power-stations, namely, 19·6 per cent. It appears, therefore, to be in the national interest that this supply of fuel should be fully utilized and the installation of the proposed super stations limited to power requirements beyond those derivable from generating plants situated, as suggested, at the coke-ovens and blast-furnaces of the country.

The CHAIRMAN (Mr. J. R. L. Allott): Those who have visited the works of the Midland Coal, Coke, & Iron Company must have been impressed by the very efficient plants which are running there, not only on coke-oven gas, but on blast-furnace gas. I have seen a number of plants of the kind in different parts of the country, but have never come across any that are better installed and kept. There are certain features of this plant that are particularly noteworthy, and about which we would like to know more, namely, the attachment to the engines that deals with the constant supply of gas, which is an excellent and simple device, and also the arrangement for softening the water and for providing pure water for cooling the engines. Anyone who has had to do with gas-engines will know that to attempt to cool them with impure water is to seek trouble. Another feature is that for overcoming the hydrogen difficulty when the engines are running on coke-oven gas. Coke-oven gas contains a considerable amount of hydrogen, which ignites at a much lower temperature than the other gases, and at the Midland Company's works a very simple arrangement has been devised for overcoming this difficulty, namely, by adulterating the coke-oven gas with some of the spent gases. More details of this device would be welcomed. With regard to the oil-supply, it is usual with high-speed engines to have an oil-pump in the crank-case. Mr. Cork has done away with that arrangement and has put in coolers and a little separate oil-pump. The oil is not allowed to remain in the crank-case when hot and be used over and over again in that state, but is passed through coolers and then forced round the bearings of the engines when almost quite cold, thus adding to their efficient running.

Mr. Hill makes a great point of thermal efficiency, but he does not tell us anything about the cost of repairs. Having had experience of gas-engines, I know that one can afford to sacrifice thermal efficiency in plant if one can cut down the cost of repairs and maintenance, which at the present time is a very serious item. My ideas of the future utilization of coke-oven gas are not in the direction of gas-engines, but of town-lighting; and I believe that we shall soon see more of our towns lighted by coke-oven gas. Birmingham and other large towns are already using coke-oven gas for lighting and general domestic purposes. It will be found more profitable to sell coke-oven gas for town-lighting at a lower price than the gas companies can produce it, instead of using it ourselves to drive engines. The extended use of exhaust-steam in turbines will be a better proposition for power production than gas-engines.

Mr. Hill's comparison of the installation of the Midland Company with the super power-station is hardly fair, because as the latter generates on a much greater scale, the cost is reduced in every poossible direction.

The plant at the Midland Company's works for cleaning the blast-furnace gas is of great interest; the method is a dry-cleaning one, and is exceedingly good for gas-engines. More details, therefore, would be of value to the members.

Mr. JOHN GREGORY (Sneyd Colliery): The authors of the paper have harnessed in a successful way what otherwise would be waste bye-products from their coking and blast-furnace plant. My experience with gas-engines is practically *nil*, but Mr. Allott has raised the question of the very heavy cost of upkeep and repairs. That alone, I have always understood, militated against the extended use of gas-engines. I gather from the introductory statement that the authors' object is to suggest that full use should be made of coke-oven and blast-furnace gases for the super power-stations that we hear talked about. I may be mistaken, but one difficulty seems to be that one of these big power-stations will probably have an output running into hundreds of thousands of kilowatts, and, so far as I know, it would be impossible to find any installation of coke-ovens or blast-furnaces to provide sufficient gas to run a plant of that size. The alternative would be to have a large number of small power-stations that would feed the central mains; but that, in my opinion, would not lead to the economical production of current. Another point is the size of the individual units, which in the paper is given as 600 horsepower. That is really very small when compared with modern turbines, where 20,000 kilowatts is a common size. I would like to know, therefore, whether 600 horsepower is regarded as an economical unit. In No. 1 Station the engines are driving alternators, and it would be interesting to know whether any difficulty is experienced in parallel running. I notice, too, that the authors do not give any indication as to the cost per unit generated. If they can give us some approximate figure, it will be of interest to the members.

Mr. G. P. HYSLOP (Shelton): I would suggest that the authors should give us more information before we attempt to discuss the paper, much less to criticize it. For example, they took very careful observations of the losses in their steam plant before they decided to make the change, and it would be helpful to those who may still have to deal with old and obsolete steam plant to have details of the sections in which the greater amount of the loss occurred, and the amount of that loss. I understand that they arrived at the loss in each part of the plant then in use, and those particulars would be most interesting and useful.

With regard to the comparative figure of 2·26 per cent., given as the over-all thermal efficiency in the old plant, and the over-all station efficiency of 20·13 per cent. of the new plant, I take it that the first figure is hardly comparable with the second, because it includes the loss in certain units that the second does not include; and as such widely different fuels were used, comparison may be misleading. It would be useful to have more details of the calculations by which the thermal efficiency was arrived at.

Whatever scheme is ultimately decided upon by the State in the way of super power-stations, supplies of surplus or waste-gases or heat that may be available will not be neglected, and these will doubtless be brought into use in any central power-stations that may be erected.

In the present critical state of the supplies of fuel the great hope held out is to make use of the gases available in coal by the many methods that are being propounded, and anyone's successful experience—such as this has been—is certainly a valuable contribution at the present time and to this Institute in particular.

Mr. WILLIAM HILL (Apedale), in reply, said: It is difficult, in the unfortunate absence of the diagrams, to convey a complete idea of the various devices that have had to be called into being for dealing with the several points to which Mr. Allott has referred, and we would therefore like to leave the discussion of them over until the illustrations are available.

Mr. Allott referred to the cost of generation as compared with that of the proposed super power-plants, and as to the cost of repairs and renewals. The object of the paper is to show that it is possible and practicable for the thermal efficiency and consequent fuel economy of power-stations using surplus gas from the coking and blast-furnace plants of the country to compare favourably with that expected from the proposed super power-plants. According to Mr. Wilson's report, these would be much more economical than the existing central power-plants, and for this reason this fuel should be fully utilized.

The average cost of repairs and renewals for the year 1918 was about 0·09d. per unit sold.

I entirely agree with Mr. Allott as to the ultimate use of coke-oven gas for illuminating and general town purposes. We, however, started our first battery of ovens eight years ago. We did not meet with much encouragement in that respect from some of the local authorities, but I think from what has happened since then that they are becoming more enlightened in that respect, or perhaps the circumstances of the times are more pressing.

Mr. Gregory, amongst other matters, referred to the size of the units. The scheme started under much uncertainty, not only from a technical but from a reliability point of view, and also on the grounds of expense and financial prudence. We decided, therefore, on the size adopted, as the initial cost was not unduly risky, and for our variable load the plant was suitable for running the sets with a reasonable high load-factor. There is now, however, no difficulty in getting up to 5,000 brake-horsepower, which, at any rate, would be a substantial contribution from this very cheap source to the power requirements of any district. Mr. Gregory also mentioned the very interesting problem of parallel running. We have had quite an experience in that respect, but have now achieved success, and are running in parallel—two 250-brake-horsepower Bellis-and-Morcom steam sets, four 600-brake-horsepower gas-engines in the coke-oven power-station, one 500-kilowatt turbo-generator, and one 600-brake-horsepower gas-engine in the blast-furnace power-station. The cost of generation is low.

Mr. Hyslop raised an important point as to the steam lost in the various sections of the plant from radiation, etc. This necessitated extensive tests on the various portions of the plant, and as the results varied considerably, owing to the local conditions of each separate unit, this involved many and diverse calculations. Mr. Hyslop and Mr. Gregory both made reference to the point as to what extent, if any, the utilization of this waste-gas from coke-ovens and blast-furnaces can help the country in the super power-stations, as suggested in the last paragraph of the paper. In the case of our ovens and blast-furnaces—and we speak well within the mark—we have gas at present available for various power purposes that is equal to 12,000 brake-horse-power in excess of anything we are likely to require in the near future, and there are numerous works in the country that are in a somewhat similar position. But the question does not quite end there. If you will take a map and plot thereon the blast-furnaces of the country, you will find established in Northamptonshire and the Midlands generally, and in other places also, blast-furnaces which, owing to the iron-ore used and its very high moisture contents, necessarily use a very large percentage of coke to the ton of iron smelted. These furnaces are, therefore, of the nature of huge producers, and in a general way it is obvious on going through these districts that the fullest use is not being made of the surplus gases at the present time.

The further discussion of the paper was adjourned.

THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE,
PICCADILLY, LONDON, W. 1., JUNE 19TH, 1919.

MR. GEORGE BLAKE WALKER, PRESIDENT, IN THE CHAIR.

PRESIDENT-ELECT.

The PRESIDENT: I regret to state that Colonel W. C. Blackett, who has been nominated as President of the Institution for the ensuing year, is not able to be present to-day, owing to illness.

I am very sorry that I find myself unable to continue to fill the office of President for a second year, and the Council have very considerately excused me. We had quite hoped that Colonel Blackett would be with us to-day, and the Council at their meeting held this morning unanimously passed a resolution expressing the hope that the time is not far distant when he will be entirely restored to health, and able to take up his Presidential duties in September.

PRESENTATION OF INSTITUTION MEDALS.

The PRESIDENT: Presentation of medals will be made to Dr. Auguste Rateau, of Paris, and M. Victor Watteyne, of Brussels, who have been chosen this year, it is thought appropriately, to represent the two allied countries who have suffered so much in the war, and to whom we have been indebted in the past for very valuable help in connexion with mining questions. Prof. Louis will receive the medal on behalf of Dr. Rateau and Sir William Garforth on behalf of M. Watteyne.

AUGUSTE C. E. RATEAU.

Auguste Camille Edmond Rateau was born at Royan (Charente Inférieure) on October 13th, 1863. Son of a distinguished architect, who was Mayor of the town, he had a brilliant career at the Boys' College, Cognac, and then at the Lycée Saint Louis, Paris. He became a pupil at the Polytechnic School, coming out at the top of the list (1881-1883); then went to the High School of Mines (1883-1886), became an engineer of the State Corps of Mines at Rodez (1887-1888), Professor at the School of Mines of St. Étienne (1888-1898), then Professor of

Industrial Electricity at the High School of Mines (1902-1910). Of late years M. Rateau has devoted himself to the industrial development of his inventions, having taken out numerous patents in every industrial country. He is President of the "Rateau Association," a limited company domiciled in Paris, with branches in Europe and the United States. He is also a Director of the "Workshops and Shipyards of Brittany," and of various other industrial corporations.

In his scientific investigations, M. Rateau has mainly studied the mechanics of fluids and the applications thereof to steam-turbines, hydraulic appliances, and centrifugal ventilators. He may be regarded as a pioneer of turbo-engines, in forms which have become gradually generalized, especially in all that concerns steam-turbines and multicellular pumps, centifrugal compressors for high pressure (now in use in mines), also for obtaining compressed air in metallurgical works to be used in connexion with blast-furnaces and Bessemer and Thomas converters. Applying turbines to the utilization of waste-steam from engines working intermittently, he has devised steam-accumulators and so-called "compound turbines," the use of which has rapidly spread through the whole world. In the course of the war of 1914-1918, he made useful improvements in high-speed turbines for aeroplane motors, so that they could retain automatically full power at the highest altitudes.

We owe to M. Rateau studies and papers on the "Belleville Springs" (1890); on Turbo-engines: Ventilators (1892); Appliances for Measuring the Humidity of Vapours (1897); Anemometers and the Pitot Tube (1898); The Theory of Propeller Screws (1900); Ejectors (1900); Ejecto-condensers (1900); Flow of Steam through Pipes and Orifices (1902); Treatise on Turbo-engines (1900); Hydrodynamic Thrust of the Air on the Wings of Aeroplanes (1909); Hydraulic Brakes and the Measurement of the Mechanical Equivalent of the Calory (1913); Experiments on Rams (1917); Steam-turbines and their Application to the Propulsion of Ships; Centrifugal Pumps and Compressors. All these papers have appeared in special serials or in the *Transactions* of the Mechanical Congresses in which he has taken part in France, England, Germany, Belgium. and America.

A recipient of awards from the Academy of Sciences (Fourneyron and Poncelet Prizes), Doctor-Engineer (*honoris causâ*) of the Technical University of Charlottenburg, Doctor of Laws of the University of Wisconsin (U.S.A.), M. Rateau was elected a Member of the Institute of France (Academy of Sciences) in 1918. He is a Knight of the Legion of Honour, and a member of Committees or Councils of the Society of Civil Engineers, Society for Promoting National Industry, Society of Electricians, Marine Technical Association, etc.

TITLES, FUNCTIONS, AND RECORDS OF SERVICE.

Engineer of the Corps des Mines (1887-1911).

Professor at the School of Mines of St. Étienne (1888-1898). Courses of Analysis, Mechanics, Engines, Industrial Electricity.

Professor at the High School of Mines (1901-1908). Courses on Industrial Electricity. Establishment of the Electrical Laboratory.

Member of Committee of the Marine Technical Association (1898), of the Committee on Mechanics of the Society for Promoting National Industry (1901), of the Committee on Mechanics of the Society of Civil Engineers (1912), etc.

President of the Administrative Council of the Association for working the Rateau appliances.

Theoretical and experimental studies on mechanical fluids (air, steam, water), and on the engines in which these fluids are made to act (ventilators and centrifugal pumps, steam turbines, propellers, etc.).

Owner of several invention patents for engines working with fluids, especially ventilators and centrifugal pumps, and steam-turbines. These patents have been widely applied in various industrial countries.

ACADEMIC AWARDS.

1899. Fourneyron Prize of the Academy of Sciences (on the report of M. Leaute) for the treatise presented on the subject proposed: "To perfect the theory of Ejectors in some way. Confirm the results achieved by experiment."

1904. Doctor of Laws of the University of Wisconsin (U.S.A.) on the occasion of the Jubilee celebration of that University, with the following remark:—"In recognition of your achievements as a Mechanical Engineer, as a contributor to the science of the flow of fluids, as a distinguished inventor of steam-turbine engines, and as an author of standard books on engineering."

1906. Doctor-Engineer (*honoris causâ*) of the Tehcnical University of Charlottenburg, on the occasion of the Jubilee celebration of the Society of German Engineers.

1908. Grand medal of honour on the occasion of the Jubilee of the Society of Mineral Industry, for innumerable applications of mechanics to the art of mining.

1911. Poncelet Prize of the Academy of Sciences (on the report of M. Boussinesq) for his work taken as a whole.

The PRESIDENT, addressing Prof. Louis: I have much pleasure in handing to you, for transmission to Dr. Rateau, the Institution Medal for the present year. Dr. Rateau's name is, of course, a household word, and I think we are adding honour to ourselves in associating him with the other holders of the Medal. In handing over the Medal to you, I trust that you will convey to Dr. Rateau the esteem in which he is held by the members of the Institution, and their grateful thanks for all that he has accomplished.

Prof. HENRY LOUIS, on receiving the Medal, said: It is a peculiar pleasure to me to have the honour of receiving this Medal and of transmitting it in the name of the Institution to Dr. Rateau. Dr. Rateau has been good enough to write to me in that connexion, and I would like to read the following free translation of his letter:—

"I should have liked very much to come to London to receive the Medal of the Institution, in order to thank the members of the Council of the Institution in person, and to take advantage of the opportunity of making their acquaintance; but unfortunately this is impossible for me, because I am ordered to a watering place in the South of France.

"I should be greatly obliged if, in transmitting my warmest thanks, you would express to the meeting how much I am grieved at this impossibility, and to say how greatly honoured I feel by the very friendly remembrance of our English colleagues, although I must naturally attribute to the body of French mining engineers the honour which is being done me.

"You are personally very familiar with the principal work that I have done as applied to mining technology. I think that it would be proper on this occasion to lay emphasis on the fact that it is principally in questions of safety that the work of French mining engineers has borne the most fruit. I would especially like to remind the members of the improvements in safety-lamps, in the ventilation of mines, and particularly in safety explosives, which we owe to men like Marsaut, Chesneau, Murgue, Mallard, and H. le Chatelier. The branch to which I have personally contributed most is almost wholly of the mechanical order—ventilation, drainage, utilization of the waste-steam of winding-engines, and centrifugal compressors."

I would like to add a few words on my own account. Dr. Rateau has laid stress on the fact that his main contributions to the technology of mining have been improvements in plant and machinery. He has devised a number of inventions of great importance in coal-mining, and notably has shown us how to economize fuel by getting the residual work out of steam that had been previously wasted. The presentation of our Medal to him comes at an opportune moment, since it serves to remind us of his services in applying engineering science of the highest order to mining operations. Even without the galaxy of famous technicians and scientists whom he has enumerated, Rateau's work alone would go far to confute the *ex-cathedra* statements that have recently been made, without any evidence to support them, as to the general inefficiency with which the coal-mining industry in this country is alleged to be conducted. When an industry so promptly avails itself of scientific inventions of so high an order as those of Dr. Rateau, it surely shows that it is keenly alive to all possibilities of improvement.

I can only say that my work brings me into close touch with a large number of the heavy industries of this country, and I can safely say that I know of none more progressive than the coal-mining industry, and more eager to take advantage of all advances in technology. I do not suggest that we have reached anything like finality; views have been expressed in some quarters that would lead us to suppose that it is thought that all the difficult geological and technical problems of coal-mining have been so nearly solved that now anyone can manage a coal-mine; for my part I do not see how such opinions can be held by any one at all conversant with the difficulty and complexity of these problems, and I say emphatically that they will become more, and not less, difficult and complex in the future, and will demand technical and scientific ability of the highest kind for their adequate solution. It is to such men as Dr. Rateau that the industry will have to look for assistance in solving them, and I am glad to have this opportunity of receiving this Medal for him, and of being able to assure him how highly the Institution values the services that he has rendered to the industry which we represent.

VICTOR WATTEYNE.

Victor Watteyne was born at Soignies on March 21st, 1850. He studied at the University of Liége for the Diploma of Mining Engineer, and thereupon in 1874 joined the Corps des Mines of Belgium. Thenceforward his life was devoted to combating the dangers that attend mining operations.

A serious mining disaster, the La Boule explosion, which occurred at Quaregnon (Couchant de Mons) on April 4th, 1887, and cost the lives of 113 pitmen, was the subject of his investigation. He traced here the undoubted influence of coal-dust, not only in the propagation, but in the initiation of the explosion.

Having thenceforward become a convinced believer in the influence of coal-dust, his convictions being further strengthened by the perusal of works published abroad, especially in England by Galloway, the brothers Atkinson, Henry Hall, F. Abel, etc., he endeavoured by means of numerous papers and lectures to direct the attention of his countrymen to the dangers of dust, at that time completely ignored.

On the other hand, being convinced of the great danger attaching to the use of explosives in fiery and dusty mines, he determined to take up this question most energetically. He did this especially by means of his "Statistics concerning the Use of Explosives in Belgian Coal-mines," which he published from 1894 onwards.

From the first, and on repeated occasions, he urged the setting up in Belgium of an experimental station on a grand scale, for the study of the problems that affect the security of mines, and more especially the important question of safety-explosives.

Having become in 1895 Chief of the section dealing with mining accidents and firedamp in the Ministry of Industry and Labour, M. Watteyne renewed his urgent suggestions, and ended in obtaining the grant required for the establishment of a testing-station for safety-lamps and explosives. And thus it is that in 1901-1902 the Frameries Experimental Station was set up on the premises of the Agrappe Colliery, a very fiery mine, yielding in abundance natural firedamp. The researches conducted at this station contributed largely to the progress accomplished in the security of mines.

In Belgium especially, since the lessons learnt from these researches have been applied to fiery and dusty mines, explosions, formerly so frequent, have practically ceased to occur, and the Belgian mines have held the world's record for safety—that is to say, they show the smallest proportion of workmen killed in relation to the number of workmen employed (10 killed annually in accidents of all kinds for every 10,000 at work).

Among the investigations carried out at Frameries, the following are worthy of mention:—

Determination of the safety-limit of explosive charges in the presence of risk from firedamp and dust.

External tamping with incombustible dust, which makes it safe to fire even the most dangerous explosives, and, if used with "safety-explosives," forms a practically absolute guarantee of security.

Determination of the degree of safety of lamps, and researches on the properties of glass, which have resulted in providing miners with lamps of a very high degree of safety.

M. Watteyne did not confine himself to the study of explosions, but extended his investigations to other categories of mining accidents. By diligent study of the attendant circumstances and the causes of accidents, he was enabled to draw up a list of precautions against the recurrence of such accidents. He investigated successively accidents in pits and working shafts, accidents (other than explosions) due to the use of explosives, accidents on inclined planes, etc.

M. Watteyne was frequently consulted by foreign Governments on questions affecting the safety of mines, and at the request, among others, of the United States Government, he went to America in 1908 with Captain Desborough, Chief of the Explosives Department at the Home Office, London.

M. Watteyne is the Secretary-Founder of the *Annales des Mines de Belgique.*

Having reached the age-limit in 1918, he asked to be allowed to retire. His request was granted by Royal Decree of January 31st, 1919, and the title of "Honorary Director-General of Mines" was conferred upon him.

The President: In presenting the second Medal to M. Watteyne, we have had placed before us the record of an entirely practical life devoted to securing the safety of mines and the workers in them. We cannot do better in that strenuous fight which is being waged against natural causes of accident than recognize what has been done by those practical men who have devoted their lives to a study of the conditions under which accidents occur and the remedies for them. I do not think that any one present in this room has done more in that direction than Sir William Garforth, and I am sure it must be a pleasure to him to be the medium of transmitting the Medal of the Institution to a colleague who has been for the last fifty years working on the same problems in Belgium and with pronounced success.

Sir WILLIAM GARFORTH, on receiving the Medal, said: I shall have very great pleasure in sending on the Medal to M. Watteyne. As the President is aware, it was not until we had met at the Council meeting this morning that I was asked to accept the Medal, and therefore I am not prepared, as Prof. Louis has been, to offer my own opinion with respect to M. Watteyne's work. At the same time, I would like to read the following letter sent by M. Watteyne to Sir Richard Redmayne:—

"BRUXELLES,
June 7th, 1919.

"Dear Mr. Redmayne,

"I have received with the greatest pleasure your letter of May 31st. I thank you very much for doing me the honour to represent me at the General Meeting of The Institution of Mining Engineers, and to receive on my behalf the Medal that the Institution has granted to me. As I wrote to the Secretary, I appreciate very highly the favour granted to me by this important English Institution, not only as an honour for me personally and a reward for my works on the prevention of accidents in coal-mines, but also as a mark more of sympathy conferred on my native country by our dear Allies and deliverers. And I pray you to repeat it to the Institution, and to express to the latter my deep gratitude and my great regret that the present state of my health does not permit me to go to England and to attend the meeting. With my kind regards, thanking you again, I remain, my dear colleague,

"Yours faithfully,
V. WATTEYNE."

I will, of course, acquaint M. Watteyne with the complimentary remarks which have been made, and I presume I may be allowed to send the little record which has been read of the great abilities which M. Watteyne possesses.

I would like to mention an incident which took place at the Committee meetings in connexion with the Brussels Exhibition. I had been asked by the Board of Trade, together with Prof. Louis and another representative from England, to be one of the jurors for the Mining Section of the Exhibition. Some twenty-three members of the Committee met regularly for some days, and in our room we were surrounded by drawings just like those which are now here, and also by about five different forms of rescue-apparatus. After some days, and wondering what we were going to do with these forms of apparatus, which I saw were very imperfect, I said to one of the members who spoke English: "What are you going to do with these forms of rescue-apparatus? Are you going to distribute medals?" "Oh, yes," was the reply; "the exhibitors will receive the Grand Prix or the Diplôma d'Honneur or the Gold Medal." I said: "Yes, and when the makers get the awards they will go about and advertise their apparatus, and within a few months there may be a dreadful explosion, and the apparatus may be used and found to be a death-trap. But the exhibitors will say: 'The apparatus received the consideration and approval of the Committee.' You therefore throw upon us, the Committee, the responsibility of approving these different forms of apparatus. I should like to see M. Watteyne." M. Watteyne came, and I put it to him very strongly that very serious responsibility would be incurred if they granted any prizes for the apparatus. I said: "This apparatus is imperfect for such a reason, and that is imperfect for another reason. We have done a great deal more to test these various kinds of apparatus in England than you have." I said so much that M. Watteyne stated that nothing more would be done. I then suggested that a letter should be written to the various exhibitors telling them how much we appreciated their kindness in sending their apparatus, which had added so much to the interest of the exhibition, but that no prizes would be awarded. A gentleman in the room came straight across to me, shook my hand, and said: "You are right," and M. Watteyne also said I was right. I am thankful to say that we incurred no responsibility in that way.

All that has been said about M. Watteyne is borne out by my own personal experience of him, and I know that he will appreciate the Medal very highly.

THE DIFFICULTIES AND DANGERS OF MINE-RESCUE WORK ON THE WESTERN FRONT; AND MINING OPERATIONS CARRIED OUT BY MEN WEARING RESCUE-APPARATUS.

By Lieut.-Colonel D. DALE LOGAN, D.S.O., M.D., D.P.H.

I.—The Difficulties and Dangers of Mine-rescue Work on the Western Front.

Introduction.—As doubtless some of the members are aware, it was largely due to the driving power of Sir John Norton Griffiths that Tunnelling Companies were so quickly formed. When I was attached to the staff of the Engineer-in-Chief in September, 1915, I had every chance of appreciating his work, his impatience with everything savouring of red tape, and his forceful methods of getting things done. I was also brought into close association with another member of the staff, Brigadier-General R. N. Harvey, to whom more than anyone else belongs the credit and honour of making the tunnelling service such a splendid self-contained one, and of bringing it to so high a pitch of efficiency. I believe that it was regarded by the general staff as a model of efficiency. When the special mining department was formed in January, 1916, General Harvey was appointed Inspector of Mines. His appointment turned out a particularly happy one. He had already done brilliant work as staff officer to the Engineer-in-Chief, and was recognized as an unusually good organizer, a restless worker, with a most orderly brain. He never spared himself, and he took very good care that no one under him spared himself. In my opinion certain things helped General Harvey. He had a very good idea of values, an attribute which was very valuable in the early days of mining. He also realized and thoroughly appreciated the ability and experience of the tunnelling officers, the many mining experts drawn from every mining district in the world, and the character and capacity of those splendid fellows, the tunnellers. The Battle of Messines is considered one of the most complete and brilliant victories ever gained by the British—a model of staff work. According to Sir Douglas Haig, the mining operations, which were the most gigantic ever attempted in the history of warfare, contributed in no small degree to the victory. Would it not be fitting, then, that General Harvey's name be associated with that of General Plumer in connexion with this glorious victory?

I was on the staff of the Inspector of Mines till January, 1919, so I may claim to know something of the tunnellers and their work. I formed the highest opinion of the officers; there were no more efficient or gallant officers in the Army. About 80 per cent. of them had been mining abroad, and had come from all parts of the world. They were inured to danger, had any amount of pluck and resource, and had been used to thinking and acting for themselves and to handling men. The result was that their men trusted them.

As for the men, one cannot speak too highly of their work. The miner makes a splendid soldier, as Sir Douglas Haig has testified on several occasions. In order to appreciate the tunnellers' work, one must remember that of the specially-enlisted miners many were over forty years of age, and a considerable number over fifty, and that they suffered from all kinds of minor disabilities. The Bosches have a name for painstaking industry, but in mining our fellows left them well behind and were easily "top dogs." I know of no units in the Army which had harder and more continuous work than the tunnellers. Many of the companies were continuously in the front line for more than two years without rest. Work was always carried out under pressure and against time. It was this factor indeed which made mining such trying and arduous work. At first, owing to their want of military training and their unsoldierly bearing, the tunnellers were regarded with a certain amount of contempt—aye, even derision—but it was not long before they were looked upon as the guides and friends of the infantry, knowing as they did every inch of the trenches.

The character of the work underground entails considerable nervous strain both for officers and men. Listening under certain conditions is particularly nerve-wearing work, and at the same time most hazardous. From the time when the listener commences work his nervous system is in a state of tension, and it is well known that tension is more exhausting than work. To this must be added the deadly monotony and loneliness of the work, and the necessity for absolute silence. In many sectors of the line, especially those situated in the clay, silent working was essential. The efficient way in which this was carried out was shown by the complete nature of the surprise at Messines. It is difficult to realize what silent working means, and to estimate the strain on the men, more especially as they were carrying out hard work all the time. The slightest noise might result in such serious consequences, and have such far-reaching effects, that every man had to concentrate his attention on working in perfect silence; and, as you all know, concentration causes fatigue to be felt more quickly.

Let me now give a few incidents to show the character of the men who carried out the work of tunnelling. In the winter of 1915, I had to parade some of the older men, who, after being in the trenches for six months, had completely broken down in health. I remember one old man whom I found going about with the aid of sticks; he was crippled with rheumatism. I asked him his age, adding, "Your proper age, not your recruiting age." The old man replied, "sixty-eight." That man had "stuck it" for months at Hill 60, which I am sure is still fresh in your memories, and was the scene of some of the hardest underground fighting during the war. In another case, just before the battle of Langemarck, a section commander of one of the tunnelling companies sent back to camp a man of fifty-eight years of age, who, he thought, was not fit to carry on, under the fierce shell-fire which was likely to be experienced, with a note to the medical officer asking him to place the man on light duty. The medical officer carried out the request, but that night the man made his way up to the trenches with his section, and next day won the Military Medal. At Givenchy the miners helped to save a critical situation; indeed, if it had not been for the work of the 251st Tunnelling Company it is almost certain that Béthune, with its valuable coalfields, would have fallen. In this sector a remarkable coincidence occurred. One of the old miners was gassed, fell down the shaft, and was killed. At that moment his grandson, who was in an infantry battalion, was on sentry near the shaft-head about a hundred yards along the trench.

In the Ypres salient, the enemy blew a mine which destroyed several hundred yards of a British gallery that was well under the enemy line. About twelve men were in the mine at the time. The rescue-party, after working for a day, found that the armoured hose for carrying air to the working-face, and the electric wires for lighting, had been injured. After eight days' hard work the gallery was cleared and eleven bodies were found in the dip; it was presumed that the twelfth had been buried. As a matter of fact, this man had retired to the working-face where he lay down; on the eighth day when he found the air had greatly improved, he made his way out. The information given by this man proved to be most interesting. After the explosion he tried to dissuade his mates from attempting to dig their way through, as by doing so they would quickly consume the little oxygen available in the gallery, and it was certain that a rescue-party was already hard at work. He urged the men to distribute themselves along the gallery to the working-face and to lie down, as by so doing they would consume less oxygen. They refused to listen to him, so he made his way to the working-face, prepared a bed of sand-bags, and lay down. After the third day, when probably the eleven men had died, he found that the air had improved. He had no food, but he had a little water in his water-bottle, with which he rinsed out his mouth, but which he was careful always to return to the bottle. It required great strength of character on the part of this man to separate himself from his mates in such a time of danger, to go far away from them and lie down; and it also required great confidence in his own judgment regarding the condition of the atmosphere and the factors which affected it. The man was found to be none the worse for his trying experience, which, I should add, was the second of its kind he had gone through. Such incidents show the character of the men who helped to win such fame for the Tunnelling Companies.

If you were to ask anyone about gas-poisoning, he would tell you when gas was first used, all about drift gas, gas-shells, and gas-bombs, and he would probably dilate on the wickedness of the Germans in introducing such a hideous weapon of warfare. How many people realize, however, that in the use of what might be termed the legitimate weapons of modern warfare in which explosives are used many casualties from gas-poisoning occurred every day?

During the war thousands of casualties from carbon-monoxide poisoning resulted from shells, trench-mortars, bombs, and aërial torpedoes bursting in deep trenches, dugouts, cellars, concrete structures, and enclosed places, as well as ships; from mobile charges used to destroy dugout systems; from bombs bursting in houses and flooding basements with gas, and from many other causes. To-day we are solely concerned with gas-poisoning in mines.

I find that it is very difficult to make people appreciate the very extensive scale on which mining operations were carried out on the western front. Mining started in the beginning of 1915, and by the autumn had made huge strides. With the great increase in size of explosive charges used in craters and in camouflets, following upon the increased depth of mines, the more extensive mine systems, and the consequent increased personnel employed, the casualties from gas-poisoning assumed serious proportions. Before a system of rescue-work and of protection against gas in mining could be organized, one Tunnelling Company in five weeks had sixteen killed, forty-eight sent to hospital, and eighty-six minor cases treated at the shaft-head and returned to the company billets. Another company in a month had twelve killed by gas, twenty-eight sent to hospital, and sixty minor cases retained with the unit. As many of these men were skilled miners, whose places it was almost impossible to fill at the time, the wastage was affecting in a very marked way the efficiency of companies.

From 1915 to June, 1917, many thousands of men were daily employed underground. It may convey some idea of the intensity of mine warfare waged and the great risk of gas-poisoning and other casualties occurring when it is stated that in 1916 the enemy fired 700 mines and camouflets and the British nearly 750. At the Battle of Messines, in which mining contributed so much to the success of operations, nineteen huge mines were exploded, some of which were charged with over 90,000 pounds of ammonal. To give some idea of the work involved, it should be stated that about 25,000 feet of gallery were driven, and the total charge of explosives in these mines was over 1,000,000 pounds. That conveys nothing regarding the many difficulties which were overcome on account of the treacherous nature of the ground in many places—for example, blue clay below running sand above—which called for the greatest skill, courage, ingenuity, and perseverance to overcome. It is not generally understood that several of the mines had been laid for twelve months, and many for nine months, and that they were still effective when required, which shows how carefully the charges had been laid. These were the result of many months' constant, strenuous, silent watching and working of a particularly nerve-wracking character; and, in order to preserve the mines until the great moment arrived, much underground warfare and crater fighting was waged and many mines and camouflets were blown.

By far the greatest number of gas-poisoning cases in mining were caused by carbon monoxide. As this gas is not naturally present in the soil, it could result only from the explosives used. Explosives used in military mining should fulfil the following conditions:—(1) reliability in action, (2) safety in handling, etc., and (3) powerful lifting and shattering effects. The production of much carbon monoxide by an explosive was a serious drawback to its use in certain circumstances, especially in blowing camouflets. In the intensive crater warfare which was waged continuously for so many months, it was frequently necessary for the infantry to occupy the craters very quickly after they were formed, and in many cases it was necessary for work to be resumed in the blown galleries as early as possible, as in the case of the defensive operations which accompanied offensive mining.

For several centuries gunpowder was the only explosive used in military mining. In this war it was very little employed in mining operations. In the early days of mining in 1915 guncotton was used, but quickly abandoned, as it gave most unsatisfactory results underground. It produces more carbon monoxide than any other explosive—over 40 per cent. if there is complete detonation, and as much as 54 per cent. if detonation has been incomplete. Experience showed that it was very difficult to clear the mine of gas after this explosive had been used, as the disturbed ground and that in the vicinity became quite saturated with gas, and there was frequently trouble when the tamping was being removed owing to gas welling out.

Nearly every explosive used in mining by the Allies and by the enemy belonged to the ammonium-nitrate group. Generally speaking, they contain an excess of oxygen and theoretically give rise to little or no carbon monoxide. But they appear to vary considerably in this respect; and in the conditions under which they were generally employed produced considerable quantities of this gas. All the explosives belonging to this group are hygroscopic, and, in the presence of moisture, large quantities of carbon monoxide are generated. Ammonal was the explosive which was most used by the British during the most active mining period. Afterwards amatol, blastine, and sabulite were employed.

Under certain conditions large quantities of carbon monoxide may be produced from all explosives. The amount will depend not only upon the type of explosive used, but upon the quality. Deterioration of the charge or of the detonators, from whatever cause, may lead to incomplete or imperfect detonation of the charge, with the consequent production of large quantities of carbon monoxide. Bad quality of explosive or of detonators, or insufficient or weak detonators, may also cause this. Some of these conditions may be produced when a charge has been poorly laid and tamped for some time in damp workings.

How Gas-poisoning was Caused (Fig. 1, Plate VII.).—When a mine was exploded, the galleries and shafts of the mine were filled with gas. There was much less trouble from gas after the enemy had fired a *mine* (crater formed) than after a *camouflet*, where the surface of the ground is not broken. It was found that when the galleries were driven through Ypresian clay, as in mining in Flanders, the mines quickly cleared of gas and the ground did not become impregnated with carbon monoxide to any degree as happened when the galleries were driven through chalk or other pervious strata. In certain cases where sufficient time had been allowed for the fumes to be dissipated and the air of the gallery proved to be free by the use of canaries, it was found that when the men commenced to remove the tamping they were frequently affected by the carbon monoxide which was liberated.

Many cases of gas-poisoning were caused, especially in the chalk areas, when the galleries were driven through ground disturbed by previous blows, or in its vicinity. In certain parts of the disturbed area large collections of gas might be tapped—these were known as "pockets of gas." The gas sometimes came through in distinct puffs, with a hissing or whistling sound, showing that it was escaping under pressure.

Fumes from explosives frequently lose their distinctive odour after percolating through the soil, and are consequently much more insidious. It has sometimes happened after a small hostile camouflet that the miners in the neighbouring galleries were so little disturbed by the explosion that they went on working. In the course of time gas penetrated to these galleries and poisoned the men there. To prevent such accidents the order " When a blow occurs, even though this appears to be a long way off, all men working below must come up at once " was issued.

Sudden inrushes of gas into galleries which were free of gas were sometimes encountered owing (*a*) to sudden settling of the ground by whatever cause (rain, another blow, etc.), forcing the contained gas into the gallery; (*b*) to changes in atmospheric pressure; and (*c*) to changes in the water-level.

On certain occasions after the explosion of an enemy mine, gas has poured from the shaft and poisoned men who were in the trenches in the immediate vicinity. In such cases serious gassing is more likely to occur where the trenches are very narrow, and also where the weather conditions (absence of wind, heavy dull atmosphere) are unfavourable for the rapid dispersion of the fumes in the open. The infantry were warned against taking shelter in the mine-shafts, dugouts, chambers, etc., from the shell fire which accompanied an enemy mine explosion, as these places became regular death-traps.

One of the most important features of the stationary trench warfare of 1915, 1916, and part of 1917 was the fighting for craters, which went on continuously. It happened frequently after a mine was exploded that only a very few minutes elapsed before the crater was occupied by the infantry, bombing posts, etc., were established, and other means taken to consolidate the position. Seeing that charges of many tons of explosive were generally used, one would have thought that there was considerable opportunity of gas-poisoning. But the loose, porous condition of the earth in the crater, the mounds (lips of crater), and ground in the immediate vicinity, allowed gas to escape readily, and as, in ordinary circumstances, this would be quickly dispersed, gas-poisoning cases among the infantry occupying the crater did not often occur. It was only when very large quantities of gas were formed, as with an incompletely-detonated mine, and when atmospheric conditions were favourable, that gas collected and poisoned the men who had rushed the crater. When these conditions prevailed, it was customary to take all the necessary precautions.

At the Battle of Messines, in order to avoid all danger from gas-poisoning, the following precautions were taken:—All trenches and shallow dugouts within 300 yards of the mines, and all mined dugouts and subways within a radius of 400 yards of the mines, were vacated before firing. The assaulting troops were ordered to avoid the bottoms of craters, and any work of consolidation was to be confined to the top, and at least 10 feet from the lip. A number of the infantry, however, who for various reasons, wounds, etc., had been forced to halt in the immediate vicinity of the craters, were more or less seriously affected by the gas. The weather conditions were in favour of slow dispersal of the gas.

In the French Army a number of serious cases of gas-poisoning occurred, men, while in the process of consolidating the crater of mines which had just been blown, having been known to fall and die in a few minutes. In some of these cases rescuers, who were not wearing apparatus, were also overcome. According to captured German documents, cases of carbon-monoxide poisoning in mine craters only occurred in very exceptional circumstances, such as when craters were occupied immediately in dull weather, more especially when the mine had detonated imperfectly.

Occasionally the gas exuding from the broken ground in the crater became ignited, forming walls or pillars of flame from a few feet to 12 feet high, which burned for hours. I think that this provides an excellent demonstration of the amount of gas formed by the detonation of large mines.

Explosion of Gas in Mines.—Gases from the detonation of a high explosive include carbon monoxide, hydrogen, and methane, all of which are combustible, and, when present in the proper proportion, explosive. Methane is never formed at the time of explosion, but results from the action of hydrogen on the oxides of carbon as the gas cools down, which it quickly does in the galleries. The greater the amount of hydrogen formed, the greater will be the proportion of methane.

When explosive gases are ignited, they do not explode at the point of ignition, but at a certain distance away. What happens is that the flame passes along at a uniform rate to a certain point, where, if there is sufficient gas to feed it, vibrations are set up, which become more and more rapid until explosion occurs. When the gas is not present in sufficient quantity, or in non-explosive percentage, the flame becomes spent. The result is that evidences of damage done to the gallery are never found at the point of ignition, but some distance away, and the men in the vicinity of where the gas has been fired suffer from burns, and not from injuries caused by the force of the explosion. The damage done to the gallery, which is generally limited to a very small area, will depend upon the force of the explosion, which will be much less where the galleries are large than where they are narrow, owing to the fact that air is an elastic medium, which deadens the effect of the explosive impulse. One grave danger from explosions of gas is the rapid flooding of the mine system by gas from the camouflet, owing to the combustion and explosion of the gas in the galleries causing a partial vacuum, so that the majority of the casualties from explosions of gas were due to carbon-monoxide poisoning.

Attention was first directed to gas explosions by a serious one which occurred in January, 1916, when a Tunnelling Company suffered considerable casualties, the officer commanding, another officer, and sixteen other ranks being killed. As this conveys a very good lesson of one of the great dangers of military mining, I shall give a short description of what occurred. The danger of carrying a naked light into a mine in which gas in small quantity was known to be present was not appreciated. In such cases it is well to remember that gas may be present in explosive amount, and that the quantity may be suddenly increased owing to various causes—for example, changes of atmospheric pressure, settling of ground saturated with gas, etc.

At 2.15 p.m. the enemy exploded a camouflet. From all accounts the explosion was not intense, and the damage done to our galleries was small. The probabilities are that the mine had been charged and tamped for some time, that the charge had deteriorated, and that part of it had been incompletely detonated, with the result that large volumes of carbon monoxide, hydrogen, and methane were formed. At the time of the explosion four officers and a considerable number of men were in the galleries. The exact positions of the officers and most of the men at the time of explosion were known (Fig. 2, Plate VII.). There is an order that as soon as an explosion occurs everyone must leave the mine, and an attempt was made to carry this out. At first gas from the camouflet came along the galleries, but not in sufficient strength to overcome those in the mine, although they began to feel the effects of it. Certainly they were not exposed to gas of sufficient strength to give rise to an explosion, for they would have been quickly overcome by it, and we know from the movements of an officer that this was not so. Suddenly there was a rush of gas from the camouflet. This passed down a branch gallery to the tranversal, when it was ignited by the candles of two men, whose caps were found here; it exploded further along the transversal, killing an officer. In certain proportions of explosive gases the explosive effect at the point of ignition is practically *nil*, and any one at that place would suffer from burns and not from the shock and injuries from the explosive wave. And this is what was found: the men who ignited the gas, and who were afterwards rescued, suffered from burns and carbon-monoxide poisoning, while at the point of explosion an officer was killed by the violence of the explosion. As a result of the explosion of the gas in the transversal, and its ignition along the branch gallery, a partial vacuum was caused, which produced another influx of gas into the galleries from the camouflet. This passed along the upcast (the direction of the circulation of air, as frequently happened after an explosion, having been altered, the downcast becoming the upcast), and led to the death of the men who were working in this part of the mine workings. Two officers were killed, one by the violence of the explosion, the other by burns and carbon-monoxide poisoning, and sixteen men lost their lives from carbon-monoxide poisoning. Splendid work was done by the rescue-men of the company, who saved a number of lives. The rescue operations on the surface were conducted under heavy shell fire.

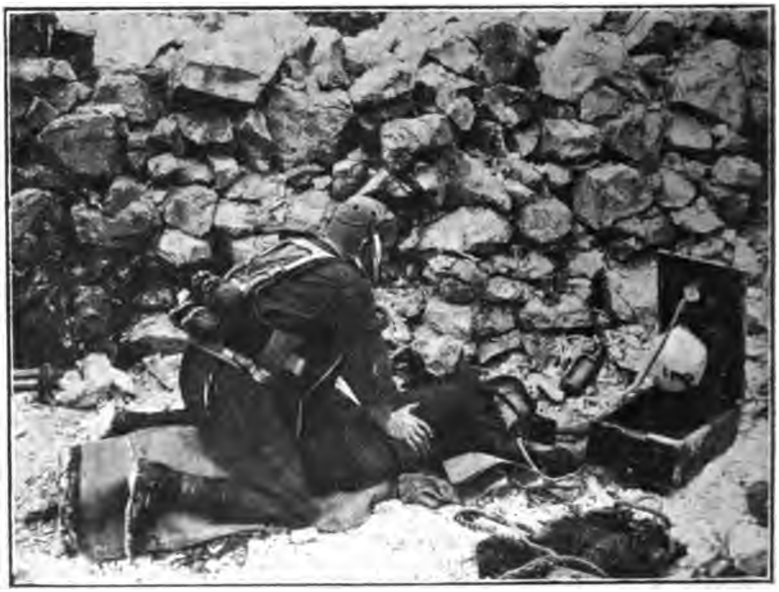

FIG. 5.—ARTIFICIAL RESPIRATION (SCHAEFER'S METHOD).

Mine-rescue Apparatus.—The Proto apparatus was the one chosen, as I considered it the simplest and most efficient rescue-apparatus on the market. For scouting, and work which did not necessitate more than half-an-hour in the mine, the Salvus apparatus was used. In deciding on an oxygen resuscitating apparatus it was necessary to remember the class of men who were to carry out first aid; therefore it should be of the simplest type and foolproof. Automatic resuscitating apparatus, the best known of which is the Pulmotor, was rejected as being too heavy and complicated for use in the trenches, besides being dangerous even in the hands of medical men. The Novita apparatus was fixed upon and modified to meet the conditions of military mining, being coupled up in a box ready for immediate use (Figs. 5 and 6 in the text). The box and handles

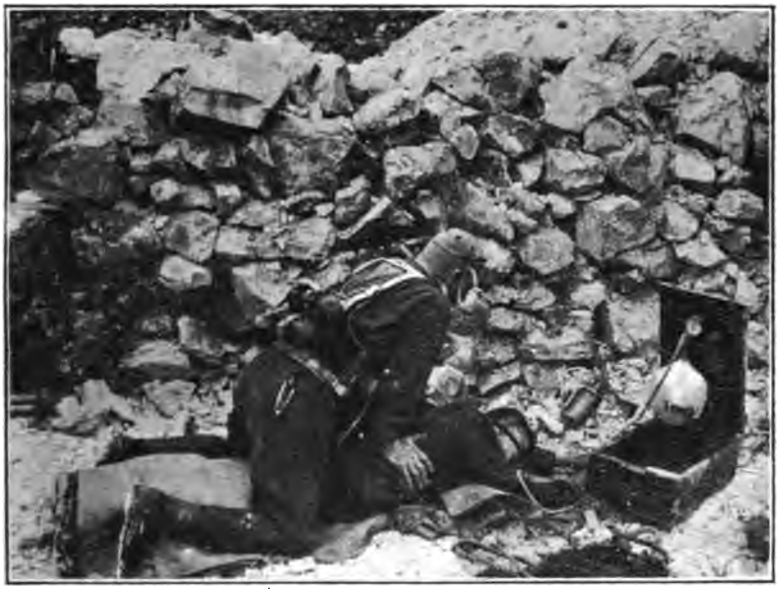

FIG. 6.—ADMINISTRATION OF OXYGEN BY MINE-RESCUE MEN.

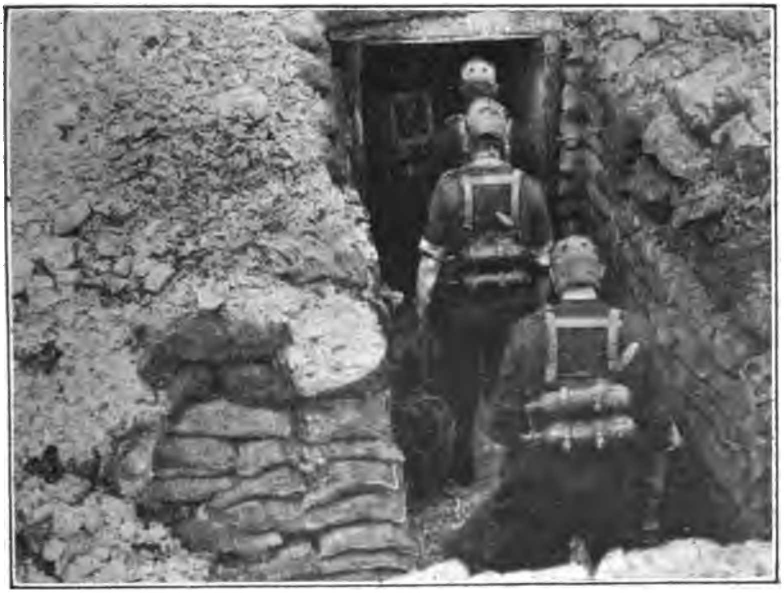

FIG. 7.—MINE-RESCUE SQUAD CARRYING MINE-STRETCHER, NOVITA OXYGEN REVIVING APPARATUS, AND MINERS' ELECTRIC LAMPS: ENTERING MINE AFTER EXPLOSION.

were arranged in such a way that it was easily carried down the shaft (Figs. 7 and 8 in the text). In rescue-work after an explosion, oxygen reviving apparatus was frequently carried below for the following reasons:—(1) When there were a number of men gassed and it was difficult to take them to the surface until further help arrived, oxygen could be administered on the spot; and (2) in serious cases it was given to drive as much carbon monoxide from the blood as might permit of the removal of the man with safety.

In the early days of mining life-lines were used for hoisting men up the shaft. The difficulties and dangers of this method of bringing up an unconscious man, the constriction of the chest wall and the serious effect this must have in certain cases, the danger of the rope slipping, and also the great exertion entailed in hauling a man along the galleries, showed the necessity of obtaining a stretcher which would be useful in the gallery and in bringing men to the surface. In a few weeks a mine-stretcher, designed by Lieut. Penman, R.E., one of the officers in charge of mine-rescue schools, was in use. From the accompanying photographs (Figs. 9, 10, and 11 in the text) it will be seen how useful this stretcher was in dragging a man along the galleries with the least possible exertion for the rescue-men, the skids on the bottom of the stretcher facilitating this. The rescue-men were so expert in the use of it that a man could be securely fixed to it in a few seconds and hoisted to the top.

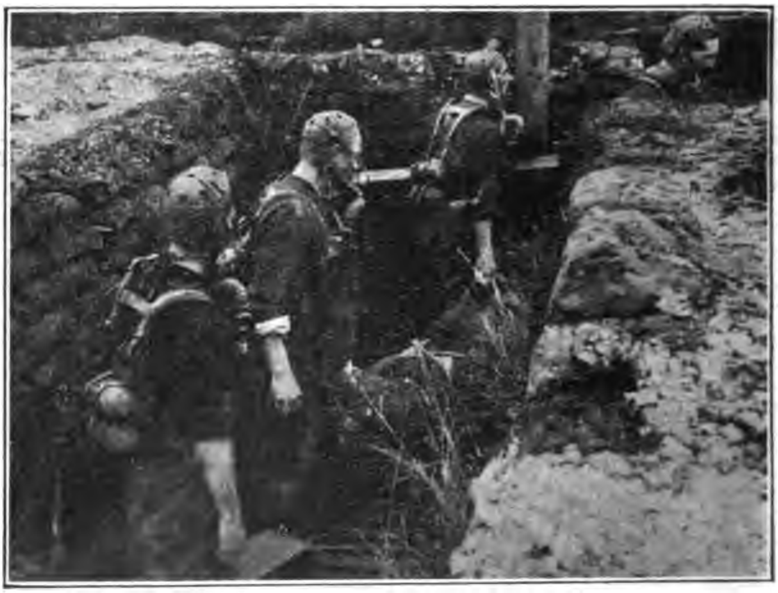

FIG. 8.—MINE-RESCUE SQUAD CARRYING GASSED MAN ON MINE-STRETCHER IN THE TRENCHES.

Mine-rescue Organization.—Before describing rescue-work in the trenches, it is necessary to say a little regarding the rescue organization and training.

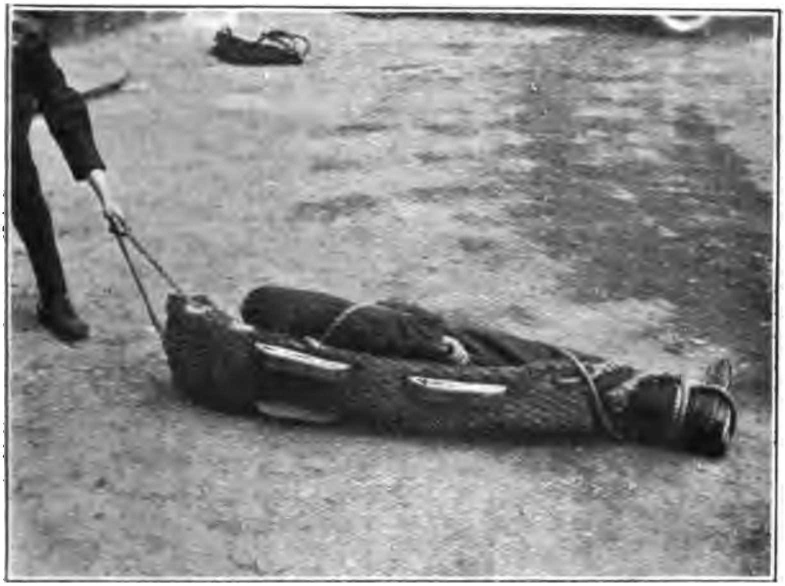

FIG. 9.—MINE-STRETCHER, SHOWING SKIDS.

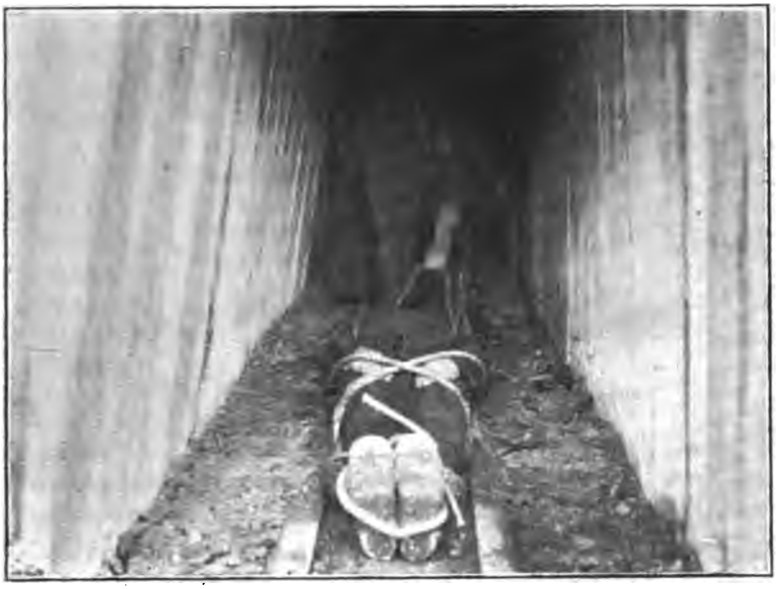

FIG. 10.—SHOWING USE OF MINE-STRETCHER IN GALLERIES.

Mine-rescue schools for the training of rescue-men were started in each army. The officers in charge of these had skilled knowledge of rescue-apparatus and rescue-work in coal-mines, and, in addition, they had the great advantage of having been previously engaged in actual mining in the trenches; they therefore knew and appreciated the actual conditions under which the apparatus was used.

In a course of training in rescue-work everything depends upon the amount of practical work carried out; no amount of theoretical work and lectures can take its place, as only in this way can one become familiar with the apparatus. From the beginning it was insisted that the training in wearing apparatus should be very searching in character, approximating as nearly as possible the work rescue-men are called on to do in the trenches. The training in the schools included working at the face, either in clay or in chalk, driving and timbering galleries, recovery and disposal of the spoil, walking quickly, climbing vertical ladders, walking up inclines, and recovering a good solid substantial dummy from under *débris*, placing it on the mine-stretcher, and bringing it to the surface. It was only by strenuous training that the men were given the necessary confidence in the apparatus, which is all important in rescue-work,

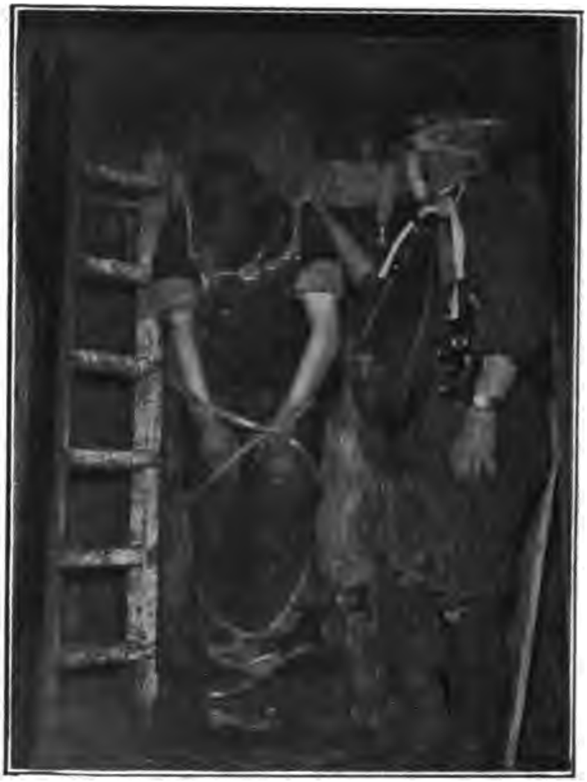

FIG. 11.—PATIENT ON MINE-STRETCHER AT SHAFT-BOTTOM BEFORE BEING HOISTED.

and permitted them to face the most trying and difficult conditions. Not only must the men be accustomed to wear the apparatus, but they must have a thorough knowledge of every part of the apparatus and its uses. There can be no doubt that the thorough knowledge of the apparatus which is obtained in this way produces confidence, as the wearer feels that, if anything should go wrong with the apparatus, he has the requisite knowledge to remedy it. I regard this part of the training as of the greatest importance.

In companies efficiency in rescue-work was maintained by weekly practices. The only possible way of getting good results from first aid in the trenches is to have a rigid line of treatment, and that all should have a thorough working knowledge of administration of oxygen and how to perform artificial respiration. Schaefer's method was the one fixed upon as the simplest, and it was the only one taught. Men practised this every day till they became expert. I have never heard of a case where damage was done to the patient by too vigorous movements, and artificial respiration must have been carried out many hundreds of times in the front line under the exciting and trying conditions met there so often at the time of a blow.

Mine-rescue stations (Figs. 1, 3, and 4, Plate VII.). in which rescue-apparatus and material were stored, were organized in dugouts in close proximity to all mines. When convenient, one station served a group of mines, but when possible they were never placed more than 250 yards away from any mine shaft. Difficulty in getting along the fire trench, owing to the condition of the trench, was taken into consideration when placing apparatus. In certain cases it was found necessary, owing to the dangerous character of the work and gassy condition of the mine, and the condition of the trenches, to keep apparatus ready for immediate use at the shaft-head. When this was done, it was kept in the cupboards specially designed for the purpose. Two trained rescue-men were in constant duty at these stations. These men had a thorough knowledge of the position of each mine served by their stations, and were familiar with the various workings.

Rescue-work in the Trenches.—In rescue-work in the trenches, the necessity of not wasting time in recovering the dead until all chance of saving others had gone was insisted on; also that the object of rescue-work is not only to save life but to prevent further accidents; consequently obedience to standing orders must always be most carefully observed.

The following incident will serve as a good example of rescue-work and of mine-recovery work, such as removal of obstacles caused by explosion, the clearing of air-pipes and re-installation of ventilation, and the dispersal of gas from the galleries—a combination of rescue-work and mining operations which was so frequently carried out along the whole front:—

Six men were at work in a mine when the enemy blew a mine. Two men who were working at the face were killed. On hearing the sound of the explosion, the rescue-men from the rescue-station made their way along the trenches to the shaft, under the heavy shelling which at that time generally accompanied mine explosions, entered the mine a few minutes after getting the alarm, and rescued four men, all of whom were unconscious, one being wounded as well by a piece of flying timber. On being brought to the surface on the mine-stretcher, the gassed men were treated by two other rescue-men, artificial respiration and the administration of oxygen being required by two of the men, who were seriously gassed; the other two quickly regained consciousness on exposure to the fresh air.

After waiting for a quarter of an hour, the same Proto men who had rescued these men descended the mine to discover the amount of damage done, and to find whether the mine was clearing of gas. A mouse which they carried with them died after they had penetrated a short way into the galleries. Having cleared obstacles from the galleries, they proceeded to install ventilation, and made it possible to resume work that evening.

The following day gas again came through into the gallery, probably as the result of settling of the ground disturbed by the blow. Three men who were rendered unconscious were rescued and brought to the surface, where oxygen was administered; the men were then wrapped in blankets, given hot-water bottles, and kept in the rescue-station for a few hours before being sent down to the aid post.

The following is an example of how prompt obedience to standing orders, and orderly and efficient supervision of rescue-work by the officer in charge, prevented more casualties and permitted work being carried out smoothly and rapidly:—

Eight men were underground in one of our mine systems at the time of an enemy blow. Of these, two were working at the face near which the blow occurred. Immediately the men made their way out, after extinguishing their lights. One reported to the N.C.O. in charge that the man who was working with him at the face was partly buried by *débris*, and that in attempting to rescue him he felt himself being overcome by gas, and thought it advisable to come back for help. The N.C.O. ordered all to the surface. The exertion of making his way out rendered the man who had been gassed unconscious. On hearing the blow, the officer in charge immediately ordered the mine-rescue men to stand-to, and they arrived at the shaft-head ready to descend within a couple of minutes after the men emerged from the shaft. They descended the shaft and found the man half covered with *débris* and unconscious. He was liberated, dragged to the bottom of the incline, placed on a trolley, and sent to the surface. Notwithstanding everything that was done for him (artificial respiration and administration of oxygen were persevered with for two hours), this man died.

If the men who were down the mine had remained to rescue their comrade, as was done in such cases so frequently in the early days of mining, instead of obeying standing orders and immediately coming to the surface, it is certain that more serious results would have occurred and the rescue-work would have been complicated and delayed.

The wonderful effect that oxygen has, combined with artificial respiration, in reviving men who have been seriously—apparently even hopelessly—affected by carbon-monoxide poisoning, and the necessity of persevering for a considerable time in efforts to resuscitate men, even though to all appearance life is extinct, was demonstrated in the following rescue-work:—

After an intense bombardment, the enemy raided our trenches and with a large mobile charge blew the entrance to the shaft leading to a tunnel in which thirty-six infantry were sheltering. Of these twenty-five lost their lives from the effects of the explosion and from carbon-monoxide poisoning before they could be rescued. Australian mine-rescue men, with apparatus from the rescue-stations, were quickly on the scene, and succeeded in rescuing and resuscitating eleven men and recovering the bodies of the others. The rescue-work was most smoothly, rapidly, and efficiently carried out. All the men who were rescued were in an unconscious condition and seriously affected by carbon-monoxide poisoning. Two appeared lifeless, and a medical officer who was present thought it hopeless to persevere. The rescue-men, however, have instructions to persevere in all such cases, which they did, and had the satisfaction, after ten hours' work, for a good part of which oxygen was administered, of saving both men. All the men required oxygen, and most of them artificial respiration.

Difficulties of Rescue-work in the Trenches.—It must be remembered that during the intensely active mining period mine explosions were frequently accompanied by fierce bombardment of the trenches, which added to the difficulties of rescue-work. Not only so, but other difficulties, some of which were unavoidable and others the result of trench warfare, best described by giving examples, made rescue operations extremely hazardous.

(1) During an enemy bombardment, a heavy minenwerfer bomb or shell pierced an officers' dugout quarters and exploded, killing three officers. Five other officers were more or less seriously gassed. Proto men from the rescue-station, who had

to pass through heavy shelling, were quickly on the scene, and succeeded in rescuing and resuscitating these officers.

Further investigation showed that the explosion had almost closed the batmen's quarters, communication being possible only through an opening which was just sufficiently large to allow the passage of a Proto man. This part of the system was heavily charged with carbon monoxide. A Proto man immediately entered and inspected the place and found six men, all of whom appeared dead. Part of the roof was destroyed, and the ground overhead, being running sand, made the place very dangerous, particularly in the vicinity of the entrance. When coming out to report, the Proto man got into difficulties, on account of his feet and apparatus becoming entangled in some electric wire, and it was with great difficulty that he was dragged to safety.

Another Proto man entered to make a further inspection, but, when near the entrance, was buried by a fall of earth. An officer who was directing operations at once freed the head and shoulders of this man and applied the mask of a Novita oxygen reviving apparatus to his face.

> "Corporal Saxton was breathing for a period of nearly two hours in this position, the mask being constantly kept applied, the cylinders of oxygen being quickly changed when fresh ones were required. Time after time we got the earth off his head and shoulders, but another fall would bury him again. On some occasions he was completely buried for a period of over a minute, but breathing was resumed with the administration of oxygen. There was only room for one Proto man to work at a time, and they were constantly relieved" (Official report).

A heavy fall at last occurred which completely buried Corporal Saxton and partly buried the Proto man, who was dragged out. When Corporal Saxton's body was recovered, it was found that his feet had become entangled in electric wire, and that wire had caught round his waist.

(2) After an enemy blow, two men who were in the mine at the time were caught by the broken timber, and they could be heard talking by the rescuers, from whom they were separated by about 30 feet of wrecked timber. After working for eight hours, the rescue-party were able to extricate both men alive.

In a neighbouring gallery in the same mine a listener was cut off. Rescue presented the greatest difficulties, as the ground was running badly, threatening to cut off the rescue-party. When the man was reached, he was found to be badly squeezed, and it was necessary to work round both sides of him before he was finally rescued, after being entombed for nearly ten hours.

(3) In another case, two men were cut off by a blow and separated by 70 feet of wrecked gallery from the rescue-party. Fortunately, the two armoured air-hoses were not quite flattened, and this not only prevented the men from being asphyxiated, but permitted communication being kept up with them. The

rescuers worked in double parties, one pushing ahead as fast as possible, and the other following up their work with temporary sets and struts to make the gallery safe. Work was still in progress twelve hours later when the enemy blew a camouflet against another part of the mine. The workings had to be cleared to test for gas, which, however, was found to be absent. Work was resumed after being suspended for an hour, and five hours afterwards the men were released.

The difficulties encountered in the trenches were sometimes so formidable as to embarrass and delay rescue operations very seriously. The following is an example:—

(4) A few days after the French part of the line at Arras was taken over by the British, the enemy sprang a mine. In this part of the line shelling had been so continuous, and the damage to the trenches so serious, that it was only held in sufficient strength to protect the mine system.

The trenches were very deep and narrow, overlooked by the enemy, and in bad repair. On the morning of the blow, it was so badly damaged by heavy shells as to be almost impassable; 12 feet to the left of the shaft the parapet had been completely destroyed the night before.

The very small dimensions of the old French incline rendered all work with Proto apparatus extremely difficult, the great exertion entailed exhausting the men very quickly. The galleries were very low and narrow (3 feet by 3 feet), and the head-room was further diminished by a 6-inch air-pipe that was attached to the roof. As the cylinders of a Proto apparatus protrude 3 inches from the wearer's back, the difficulty of passing down this gallery will be understood.

Immediately following the explosion of the mine there was a very violent inrush of gas, which not only flooded the mine, but passed up the shaft and flowed along the trenches, where it rendered unconscious a number of infantrymen, and a mine-rescue man who was coming along the trench from the mine-rescue-station, was also overcome before he could apply the mouthpiece and nose-clips of the apparatus he was wearing: the custom being to apply these when the men reached the shaft. The experience of gas flowing along the trenches was an unusual one, and is explained by the narrow deep character of the trench, and by the atmospheric condition, which did not favour rapid dispersal of the gas.

As the trench was so congested, it was necessary to clear it before rescue operations in the mine could proceed; the men who had been overcome were treated with oxygen and removed.

In the circumstances, it is not to be wondered at that rescue operations in the mine were considerably delayed. Fortunately, trench conditions such as were encountered on this occasion were seldom seen, the galleries of our mines and all the approaches being very much larger.

Rescue-work at Fires in Mines and Dugouts.—There is no more dangerous and terrifying accident than a fire underground. It is not difficult to realize that in such confined places, where the galleries are comparatively narrow, the slightest confusion may lead to the most serious consequences. Owing to the way in which mines and dugouts are ventilated, with upcast and downcast shafts or inclines, the fumes are quickly carried through the workings, and gas-poisoning may quickly occur at points at a considerable distance from the fire. In the event of a fire breaking out in a dugout, men are very apt to get confused and their sense of location blurred in the presence of dense smoke, and instead of making for safety may approach nearer the danger zone.

The mine rescue-men were frequently called upon to deal with fires in dugouts, and their work proved of the greatest value, saving a considerable number of lives and much valuable material. They were ready at all times and never failed to answer calls for help from the infantry, and one can hardly picture more trying or hazardous work than that of extinguishing a fire in a dugout. The tunnellers were soon recognized as experts in this work, and in the great fires at Arras and Béthune, which threatened to destroy these towns, it was the tunnellers who were called upon to deal with the situation, and this they successfully did.

In the rescue-stations asbestos hoods and coverings for the Proto apparatus, so as to give protection against heat, were stored.

Fires in mines were rarely encountered. A most unusual one occurred after an enemy blow as the result of three heavy explosions of gas, the gas being ignited by naked lights.

The following order, pointing out the rapidity with which fires spread in dugouts, with consequent loss of life and valuable property, and the precautions to be observed, was circulated, and from time to time brought to the notice of all ranks:—

"(1) Underground cookhouses will be provided with a door covered with tin, and a number of filled sandbags will be kept in a suitable position, so that, when a fire breaks out, the doors can be shut and a barricade of sandbags rapidly constructed to isolate the fire. Buckets of sand will be kept near each cookhouse to extinguish small fires.

"(2) When a fire breaks out underground, the officer, N.C.O., or man responsible for giving warning will clear everyone at once out of the whole system, sending the men out in one direction, if possible away from the fire. As the fumes are poisonous and far-reaching in their effects, the entrances and trenches in the vicinity must also be kept clear of men.

"(3) All tins containing petrol will be clearly marked PETROL.*

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* This was necessary on account of the fact that petrol tins were so largely used for carrying up water to the trenches.

"(4) In extensive dugout systems, isolation doors, with handy stores of sandbags on each side of them, will be constructed at suitable points.

"(5) If a mine-rescue station is situated in the vicinity, a notice should be posted in all dugout systems showing its position. The men on duty at the station are available to render assistance in rescuing men and extinguishing the fire.

"(6) Security is best assured by holding frequent fire drills."

II.—MINING OPERATIONS CARRIED OUT BY MEN WEARING PROTO APPARATUS.

When rescue-men became available, they were frequently used to lay armoured hose, in order to clear the mine of gas and restore ventilation immediately after an enemy blow. In this way, valuable time was gained. Examples of the usefulness of rescue-men recovering mines after the completion of rescue-work have already been given. The first of those now to be described was frequently met with; the second was the biggest military mining operation ever attempted by men wearing apparatus; the third was another excellent example of charging and tamping a mine; while the fourth enabled a very important mine to be blown at the Battle of Messines.

(1) Two men were caught in a gallery that had been wrecked by an enemy blow. The work of clearing the gallery was carried out immediately by mine-rescue men wearing Proto apparatus, who worked in pairs in 30-minute shifts. On account of the damage done to the gallery and the small size (2 feet 3 inches wide), work was slow, as only one man could work at a time, the other standing by in case of emergency and acting as relief.

While this work was being carried out, the air was tested with canaries and mice from time to time. About an hour after the blow, it was found that the air had cleared, but the men continued working in apparatus, fortunately, as shortly afterwards there was an inrush of gas, and a canary exposed to this was immediately killed. Air-pumps were rigged up, and air-pipes led in to clear the galleries of gas. Work was carried on for six hours.

(2) *Mine Charging and Tamping by Rescue-men wearing Proto Apparatus.*—Owing to repeated blows, the ground in an important mining sector had become saturated with gas, and in attempting to work in this area a considerable number of men had been gassed. The enemy had approached underground within striking distance of our trenches, and it was absolutely essential for the safety of the line that the enemy should be held. Gas had been entering the galleries continuously from an enemy mine fired two weeks previously, and could not be sufficiently overcome by pumps to render ordinary charging operations practicable. Work being almost at a standstill, it was resolved to charge and tamp a mine with the aid of

men working with Proto apparatus. Seventeen rescue-men of the company were employed under the control of Lieut. R. C. Smart of the First Army Mine-rescue School.

The gallery ran out 100 feet from the bottom of a vertical shaft 80 feet deep, with a 16-foot chamber at the end. While the length of the gallery was very favourable—few mines being charged so close to a main shaft—the dimensions and conditions were unfavourable, the last 40 feet measuring only 3½ feet by 2½ feet, and having shaken sides and a bad floor.

(i) *Organization of Work.*—Personnel: two officers and seventeen rescue-men. These were distributed as follows:—

(*a*) At rescue-station: four rescue-men. Two, with the aid of a fatigue man, charged and supervised all apparatus before issue. The other two stood by, in readiness for rescue-work and for treating gas-poisoning cases.

(*b*) In the mine: one officer and thirteen rescue-men, divided into two shifts: (1) officer and six men; (2) N.C.O. (company instructor) and six men.

(ii) *Distribution of Apparatus.*—For work in mine: fourteen Proto sets; reserve at rescue-station: four Proto sets.

Novita oxygen reviving apparatus and mine-stretchers were kept at the shaft-bottom, and arrangements were made at the surface and underground for treatment of gas-poisoning cases.

The duty of the first shift was to see that the shaft was cleared of all obstruction liable to foul apparatus, that hose and leads were well tied back, and that miners' electric lamps were fastened in the shaft and gallery, as good light was essential.

Charging by rescue-men with ammonal in 50-pound tins was impracticable, and double sandbags containing about 20 pounds of explosive were used instead.

During a period of 43 hours the two shifts worked in reliefs of about two hours. It took seven hours (including a break of one hour in order to see the effect of tamping on the gas) to put in 5,000 pounds of ammonal, the last 1,000 pounds being placed in an hour. Altogether 65 feet of solid tamping were put in, the actual time taken to put in the charge and tamping being sixteen hours. Eighty-six twin cylinders and ninety miners' electric lights were used, a liberal reserve of apparatus and spares having been provided by the school. During periods of resting, numerous odd jobs in connexion with ventilation, lighting, etc., were done. Actually each man did about ten hours' work underground. There was no accident from defective apparatus, which speaks volumes for the efficiency of the school junior instructor (Sapper Truman, R.E.) who supervised all apparatus before issuing it to the men.

The charge was laid and the mine sprung in time to save the situation.

Lieut. Smart was responsible for all the arrangements made, and he personally supervised the work in the mine. The men had implicit confidence in him, and his orders were carefully obeyed. For this splendid work, which saved a critical situation, Lieut. Smart was awarded the Military Cross and Sapper Truman the Military Medal.

The successful issue of these operations emphasizes the importance attaching to the following details:—

(*a*) Squads should be organized so that continuous work can be maintained.

(*b*) Spare rescue-men must be detailed to stand by for emergencies.

(*c*) Every effort should be made to ensure that every man is thoroughly conversant with (1) his duties, (2) the nature of the work to be done, (3) the rules to be observed, and (4) the code of signals.

(*d*) The physical condition of the men must be carefully watched.

(*e*) Accommodation for re-charging apparatus near the mine must be arranged for.

(*f*) Hot coffee must be ready for shifts of men coming off duty. Fluid nourishment is best; full meals must be avoided.

(3) In a certain mining sector, owing to the large number of blows, the ground had become saturated with gas. While driving through this area, considerable trouble was experienced with men being gassed. As it was of vital necessity for the safety of the mine system that work should proceed, the officer in charge resolved to use Proto apparatus to complete the work. The following work was carried out by men wearing rescue-apparatus:—

The chamber of the explosive charge which had been started was completed by pick-work. In loading, Proto apparatus was used during the whole of the first day, a considerable part of the second day, and for four hours on the third day while tamping was being put in. After tamping had been completed, no further trouble from gas was experienced.

Two men worked in the morning and in the afternoon shifts, working for 1½ to 2 hours at a time. In a shift of 8 hours, they were able to go down twice for 3 hours. One man after working for 2 hours went down again after an hour's rest. These men made no complaint after completing their shift, and were not in any way exhausted or affected by the work.

(4) The enemy blew a camouflet which destroyed a considerable part of a gallery, cutting off more than 1,000 feet of gallery leading to a chamber which had been completed and ready for charging, and was to be one of our biggest and most important offensive mines at the Battle of Messines. It was

found necessary to re-drive the gallery. While this was being done, constant trouble from gas was experienced but overcome. Later on, however, there was an inrush of gas, which led to the death of three men. The bodies were brought to the surface in fifty minutes by rescue-men who had to travel 2,500 feet in a very narrow gallery.

In order to recover the rest of the gallery, it was resolved to work round the affected area, which appeared to be saturated with gas. But before work could be recommenced, it was necessary first of all to build off the affected area and to improve the ventilation. This work was carried out by the company rescue-men wearing Proto apparatus, under the direction of Corporal Parry, the assistant instructor at the mine-rescue school, in place of the company instructor, who had been killed a few days before.

Work was started on April 30th and was completed on May 4th, 1917. The first work consisted chiefly of coupling and uncoupling the air-pipes at various points in the gallery, and testing how far in a fresh-air base for operations could be placed. On the second day the electric pump broke, and two men uncoupled the air-pipe and connected it to a Holman hand-pump. Later on, by hard work, the laying of air-pipes right up to the face was completed. Next day gas was discovered at the face, a canary being affected in five minutes; 15 feet of tamping were then put in, but as gas still came through, a large gas-tight dam was built. This consisted of 20 feet of solid tamping, measuring 4 feet 3 inches by 2 feet 3 inches, which took 4½ hours to complete, as only one man could work at a time. Just when this had been completed, the enemy blew a mine, which, fortunately did not damage this gallery. The rescue-men in the mine retained their self-possession and proceeded out calmly. After resting, they went back to investigate the damage. This splendid work allowed 1,200 feet of gallery to be recovered, the mine being charged and tamped the day before it was required. The work of this company in overcoming the gas difficulties, which at one time were so serious as to threaten the abandonment of this mine, was characterised by indomitable pluck and perseverance. This mine was the biggest one blown at the battle of Messines, the charge being considerably over 90,000 pounds.

III.—Flooding of the Béthune Coalfield with Lachrymatory Gas by the Enemy.

I am sure that the members of the Institution would like to hear about what must be considered one of the most extraordinary incidents in the war and quite unique in warfare.

Although one of the collieries (Fosse 8) in this very important mine system was in the enemy lines, and all the shaft-heads and the mining villages of Philosophe, Annequin, Vermelles, etc., were within easy range of the enemy, and had been frequently shelled, the French had been able to continue working, although the output of coal had been considerably reduced.

In September, 1917, at the height of the submarine warfare and when coal was urgently required by the French, the enemy made a determined effort to prevent the French from working the Béthune Collieries. To prevent the flooding of the whole system, the French had installed pumps near Fosse 8, which, I should add, was the downcast shaft for the whole system. A guard had been placed at this point. As unusual activity had been reported at this shaft-head, one of the Tunnelling Companies (170th) was asked to detail a permanent guard for duty in the mine, and the French miners at once commenced building a stopping as the enemy appeared to be preparing to destroy the shaft at Fosse 8 which would flood the whole Béthune area. The stopping was nearing completion when the enemy flooded the mine with chloropicrin, a very powerful lachrymatory gas. A signaller escaped, and gave the alarm. The whole of the Tunnelling Company guard, and all the French miners who were at work on the stopping, were unable to make their escape and perished.

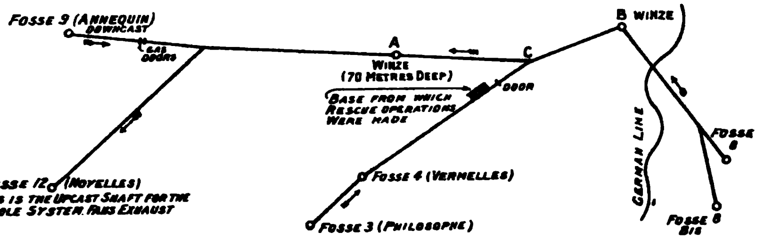
Fosse 9 (Annequin) Downcast
Gas doors
A
Winze (70 Metres Deep)
C
B Winze
Door
Base from which rescue operations were made
Fosse 12 (Noyelles)
This is the upcast shaft for the whole system. Fans exhaust
Fosse 4 (Vermelles)
Fosse 3 (Philosophe)
German Line
Fosse 8
Fosse 8 Bis

FIG. 12.—SKETCH-PLAN OF THE BÉTHUNE COLLIERY SYSTEM. NOT TO SCALE.

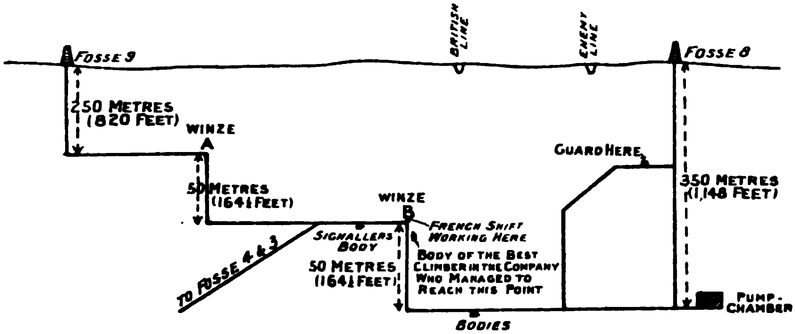
Fosse 9
British Line
Enemy Line
Fosse 8
250 Metres (820 Feet)
Winze A
50 Metres (164½ Feet)
Winze B
Guard Here
350 Metres (1,148 Feet)
To Fosse 4 & 3
Signallers Body
French Shift Working Here
50 Metres (164½ Feet)
Body of the best climber in the Company who managed to reach this point
Pump-Chamber
Bodies

FIG. 13.—DIAGRAMMATIC SECTION ON A LINE BETWEEN FOSSE 9 AND FOSSE 8.

Rescue-parties were quickly organized by the Tunnelling Company and several attempts were made to reach the men, but these failed, because it was found that the gas was present in such concentration that after 1,600 yards had been traversed, gas came through the face-piece of the box-respirator. Rescue-operations at this stage were rendered more difficult by the enemy shelling the shaft-heads in our lines with gas-shells. One of the rescue-parties on coming to the surface was exposed to this, and all the members were more or less seriously affected, the officer in charge of the party dying next day from the effects.

Special respirators were now improvised, the masks and drums of which could stand prolonged exposure to high concentrations of gas. After several attempts, rescue-parties recovered all the bodies. Strenuous efforts were now directed to clearing the mine of gas, in order to permit the French miners completing their task of sealing off Fosse 8 from the rest of the mine system. Their efforts proved successful.

A short summary of the conditions under which work was carried out by the rescue-parties will give some idea of the terribly trying and arduous character of the work:—

(1) The gas was present in great concentration.

(2) The arduous character of the work—climbing many hundred feet of ladder (one shaft was over 1,000 feet deep), traversing long roads, carrying out such work as putting up brattice, making stoppings and effecting changes in the ventilation, carrying bodies on stretchers.

(3) The length of exposure to the gas, owing to the length of the roads to be traversed, which might be 2 or more miles.

(4) The defective light underground, which calls for the best possible type of eye-piece. Any eye-piece which dims readily is a danger in this class of work, more especially as the roads are often bad, and unless clear vision is possible, such accidents as falling down winzes, a clear drop of 80 feet, might occur. The experience gained in these rescue-operations pointed to the necessity of the officer in charge of the party personally supervising the cleaning of the eye-piece of each member of the working party.

Although the gassing of the Béthune Collieries resulted in regrettable loss of life, the enemy failed to achieve his object of flooding the mines by first gassing the guard and preventing the carrying-out of any work in the mine, and breaking the tubbing of the shaft in his line. Owing to the wonderful resource, devotion to duty, untiring efforts, and bravery of the Tunnellers, who all realized what the loss of these collieries would mean to the Allies, a dangerous situation was saved and a most valuable coalfield preserved.

Fig. 12 in the text is a sketch plan of the Béthune colliery system and Fig. 13 a diagrammatic section on a line between Fosse 9 and Fosse 8.

ACCIDENTS DUE TO STRUCTURAL DEFECTS OF APPARATUS OR INJURY TO APPARATUS; AND THE FUTURE OF THE PROTO APPARATUS.

By Lieut.-Colonel D. DALE LOGAN, D.S.O., M.D., D.P.H.

I.—Accidents due to Structural Defects of Rescue-apparatus or Injury to Apparatus.

Introduction.—Guarding against defects in apparatus for which the makers are responsible—in other words, proper control over workmanship—is absolutely essential, and I am in full agreement with the following recommendation of the Mine Rescue-apparatus Research Committee regarding this:—

> "It seems to us that, as the Legislature has required the provision of rescue apparatus, official action should be taken to guard against risks of this character. In our opinion the best way of so doing is to prohibit the use of breathing apparatus in mines under the Coal Mines Act unless the apparatus be 'of a type for the time being approved by the Secretary of State.' The restriction should also apply to materials supplied for charging and repairing such apparatus. There would then be the same control over design and workmanship as now exists in the case of safety lamps."*

This control would not, of course, do away with the necessity for the most careful storing and supervision of all apparatus after issue, as the vast majority of accidents due to faults in apparatus are caused by improper storing and want of supervision. The careful testing, control, and supervision of apparatus in our mine-rescue schools, companies, and in the trenches contributed greatly to our immunity from accidents during training and actual mining operations. I should add that accidents from actual defects of apparatus were remarkably few, which is a testimonial to the careful workmanship of the makers.

I shall now describe in detail two fatal accidents which happened during rescue operations, as they convey important lessons, and at the same time will note briefly the various ways in which accidents may result.

(1) *Fracture of the Brass End of the Oxygen Tube, due to Defective Casting.*—This has happened several times, and on one occasion led to the death of a rescue-man while important rescue operations were in progress. This man went in to rescue another and was overcome; before his rescue could be effected

* *First Report of the Mine Rescue Apparatus Research Committee,* 1918, page 13.

but these failed, because it was found that the gas was present in such concentration that after 1,600 yards had been traversed, gas came through the face-piece of the box-respirator. Rescue-operations at this stage were rendered more difficult by the enemy shelling the shaft-heads in our lines with gas-shells. One of the rescue-parties on coming to the surface was exposed to this, and all the members were more or less seriously affected, the officer in charge of the party dying next day from the effects.

Special respirators were now improvised, the masks and drums of which could stand prolonged exposure to high concentrations of gas. After several attempts, rescue-parties recovered all the bodies. Strenuous efforts were now directed to clearing the mine of gas, in order to permit the French miners completing their task of sealing off Fosse 8 from the rest of the mine system. Their efforts proved successful.

A short summary of the conditions under which work was carried out by the rescue-parties will give some idea of the terribly trying and arduous character of the work:—

(1) The gas was present in great concentration.

(2) The arduous character of the work—climbing many hundred feet of ladder (one shaft was over 1,000 feet deep), traversing long roads, carrying out such work as putting up brattice, making stoppings and effecting changes in the ventilation, carrying bodies on stretchers.

(3) The length of exposure to the gas, owing to the length of the roads to be traversed, which might be 2 or more miles.

(4) The defective light underground, which calls for the best possible type of eye-piece. Any eye-piece which dims readily is a danger in this class of work, more especially as the roads are often bad, and unless clear vision is possible, such accidents as falling down winzes, a clear drop of 80 feet, might occur. The experience gained in these rescue-operations pointed to the necessity of the officer in charge of the party personally supervising the cleaning of the eye-piece of each member of the working party.

Although the gassing of the Béthune Collieries resulted in regrettable loss of life, the enemy failed to achieve his object of flooding the mines by first gassing the guard and preventing the carrying-out of any work in the mine, and breaking the tubbing of the shaft in his line. Owing to the wonderful resource, devotion to duty, untiring efforts, and bravery of the Tunnellers, who all realized what the loss of these collieries would mean to the Allies, a dangerous situation was saved and a most valuable coalfield preserved.

Fig. 12 in the text is a sketch plan of the Béthune colliery system and Fig. 13 a diagrammatic section on a line between Fosse 9 and Fosse 8.

ACCIDENTS DUE TO STRUCTURAL DEFECTS OF APPARATUS OR INJURY TO APPARATUS; AND THE FUTURE OF THE PROTO APPARATUS.

By Lieut.-Colonel D. DALE LOGAN, D.S.O., M.D., D.P.H.

I.—Accidents due to Structural Defects of Rescue-apparatus or Injury to Apparatus.

Introduction.—Guarding against defects in apparatus for which the makers are responsible—in other words, proper control over workmanship—is absolutely essential, and I am in full agreement with the following recommendation of the Mine Rescue-apparatus Research Committee regarding this:—

> "It seems to us that, as the Legislature has required the provision of rescue apparatus, official action should be taken to guard against risks of this character. In our opinion the best way of so doing is to prohibit the use of breathing apparatus in mines under the Coal Mines Act unless the apparatus be 'of a type for the time being approved by the Secretary of State.' The restriction should also apply to materials supplied for charging and repairing such apparatus. There would then be the same control over design and workmanship as now exists in the case of safety lamps."*

This control would not, of course, do away with the necessity for the most careful storing and supervision of all apparatus after issue, as the vast majority of accidents due to faults in apparatus are caused by improper storing and want of supervision. The careful testing, control, and supervision of apparatus in our mine-rescue schools, companies, and in the trenches contributed greatly to our immunity from accidents during training and actual mining operations. I should add that accidents from actual defects of apparatus were remarkably few, which is a testimonial to the careful workmanship of the makers.

I shall now describe in detail two fatal accidents which happened during rescue operations, as they convey important lessons, and at the same time will note briefly the various ways in which accidents may result.

(1) *Fracture of the Brass End of the Oxygen Tube, due to Defective Casting.*—This has happened several times, and on one occasion led to the death of a rescue-man while important rescue operations were in progress. This man went in to rescue another and was overcome; before his rescue could be effected

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* *First Report of the Mine Rescue Apparatus Research Committee,* 1918, page 13.

he died. The following report on the apparatus was rendered by the O.C. Mine-rescue School:—

> "The nipple securing the oxygen-supply pipe to the reducing-valve was broken; the part was defective, being eccentrically bored, with the metal twice the thickness on one side of the bore compared to the opposite side. Any sharp blow, such as might be caused by banging the apparatus against the side of the gallery, stumbling over a trolley, etc., could easily cause this defective nipple to snap, and although the rubber pipe might keep in position, the bulk of the oxygen from the reducing-valve and bye-pass would escape at the break and not get into the bag. This man was found half sitting against the side of the gallery, with his nose-clip off, his cap pulled off his head, and lying on his chest. He had died of CO poisoning. Being unable to get any oxygen from this bag, it would be a natural action to pull off his cap and nose-clip. I have known of one other case of this nipple failing during use in practice at the School. I wrote to Col. Dale Logan regarding the matter at the time, and also sent him the defective part of the nipple; the point was referred to the makers of the apparatus" (G. F. F. Eagar, Lieut., R.E.).

The use of some of the modern high-tensile alloys would probably eliminate such troubles.

(2) *Accidents from Loose Joints, Valves, etc.*—(*a*) *Main Valve.*—In order to prevent the main valve of the oxygen cylinders of the Proto from becoming accidentally turned off by knocking against anything, check-chains with hook-springs were used to lock the valve. In the early days of rescue-work the men removed many of these on which to suspend their knives, and several accidents occurred owing to the want of them. Happily, none was serious, and afterwards more effective control of apparatus prevented this from happening. The hook-spring may also break whilst the apparatus is in use, and if this is not noticed the valve may be closed accidentally.

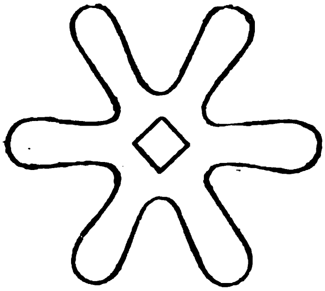

FIG. 1.—WHEEL FOR WORKING PROTO VALVE.

According to one of the officers, some men made a practice of putting on the check-chain with the main valve closed. This is very bad, as, when in a hurry, it is quite possible that the valve will be opened only as far as the slack of the chain will permit, and during use may be accidentally closed. The use of the main valve was carefully impressed on all pupils, who were told to open it two full turns before locking, and not to touch it again until work was completed. On no account was the main valve to be locked when the valve was closed.

The design of the Proto valves—main, bye-pass, and pressure-gauge—is poor. The main valve was always a source of trouble, as it was so difficult to manipulate. This was specially troublesome when the wheel became covered with clay and greasy chalk. In order to lessen this difficulty, wheels of the type shown in Fig. 1 were used, but it was found that the valve-spindle would not stand the extra strain.

It was difficult to keep the valve tight, owing to the arrangement of the packing-box round the spindle. In order to prevent leaks, it was found necessary to keep the valve-spindle so tightly packed that excessive wear resulted, the threads of the spindle, both male and female, frequently being stripped, and the packing constantly required to be renewed. The valves were very apt to stick when being turned off. Another drawback was that by continuing to rotate the valve the spindle was withdrawn, with the result that all the oxygen was lost. The check-chain was used to prevent this happening. It is a cumbrous contrivance, and its drawbacks have already been discussed. The main valve should be fitted with the new locking contrivance now on the market.

A new Proto valve (Fig. 2) has been designed, which is a great advance on the old. The construction is such that less pressure is required to open and close it; consequently the wear on the valve-spindle thread and packing is considerably reduced. The valve-packing will, therefore, not require such frequent renewal. I saw one valve which had been in constant use many times a day for six months calibrating valves, and it had stood the test. The whole valve is much more easily manipulated than the old one.

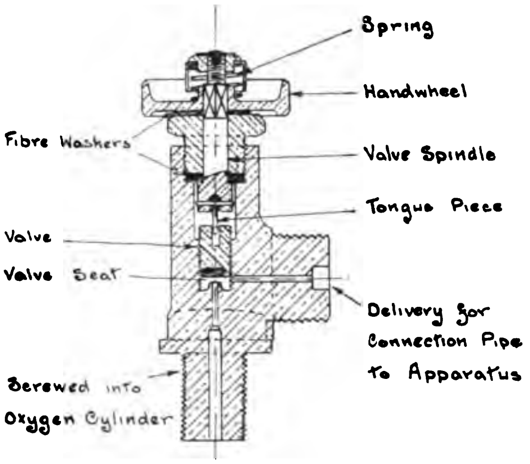
Spring
Handwheel
Fibre Washers
Valve Spindle
Tongue Piece
Valve
Valve Seat
Delivery for Connection Pipe to Apparatus
Screwed into Oxygen Cylinder

FIG. 2.—SPECIAL MAIN VALVE FOR PROTO APPARATUS.

There is no stuffing-box, the valve-spindle revolving, and not working vertically up and down, which effectively holds the pressure when the valve is open. The valve itself is threaded on the outside, and screws into the body of the valve above the seat, as shown; it is operated by a steel tongue-piece, pivoted in the bottom of the spindle, which engages in a slot in the top of the valve. By revolving the hand-wheel, the valve is caused to rise and fall from its seat. When fully opened, the valve causes the spindle to jamb up tightly on the fibre washer, thus making an effective joint.

The advantages of the valve are: (1) it is easy of operation; (2) there is no stuffing-box for the spindle, with the usual attendant leakage; and (3) there is positive closing and positive opening without leakage.

(*b*) *Reducing-valve.*—This joint is occasionally loosened by a blow during operations. It should be screwed up as tightly as possible.

(*c*) *Bye-pass.*—It has sometimes happened during training in the mine-rescue schools that the bye-pass was open when the main valve was turned on; occasionally it has been opened by repeated rubbing during use. The remedy is to make sure that the valve is always tightly closed. The sudden rush of oxygen may (1) burst the rubber oxygen-supply pipe, (2) burst the breathing-bag if it is defective, (3) blow the mouthpiece out of the wearer's mouth, and (4) in every case waste a considerable amount of oxygen.

The following is an example of how neglect of the most elementary precautions in connexion with apparatus by a skilled instructor led to his death:—

In order to carry out scouting work in a gallery which was flooded by gas from an enemy camouflet, and which was preventing the carrying-out of important offensive operations, an officer asked the company instructor to accompany him. The instructor gave the officer his own apparatus, and put on one himself which was in such a condition that it was difficult to believe that he ever had any intention that it should be worn. The gauge only showed 60 atmospheres when the apparatus was put on. When nearly 2,000 feet along the gallery, he complained to the officer of giddiness and suddenly collapsed. The officer made a great attempt to rescue him, but after carrying him some distance realized that he would require help. By the time more rescue-men appeared the instructor was dead. He was found lying full length with mouthpiece in position and firmly strapped to the cap, nose-clip on nose, main valve open and locked. The following is the report by the O.C. mine-rescue school on the examination of the apparatus:—

"On examining, I found everything in order except for two joints, which were not properly screwed up; the upper joint on the valve-box of the inhaling tube was loose a full half turn, and the fact that the flexible pipe from inhaling-valve to mouthpiece was free from any kink proved conclusively that the apparatus had been worn with this joint loose. The joint from saliva-trap on to the bag was two full turns loose. The rescue-men who recovered the body were positive that these joints could not have been shaken loose whilst the body was being brought out on the trolley, as at no time was there any serious jolting of the trolley. With either of these joints loose, the apparatus would be unsafe to wear in the presence of CO, on account of the probability of internal leakage.

"I subsequently re-arranged another apparatus in exactly the same manner as this man's apparatus, and a low-pressure test gave positive leakages at both joints. During the working of the apparatus the joint on the inhaling side would be subject to a very slight negative pressure; the loose joint on the exhaling side might cause CO to be drawn into the apparatus, by reason of the exhaled air passing down through the joint on to the bag having a slight injector effect."

During my enquiry into this accident, I examined the body. Death was due to carbon-monoxide poisoning. From the life-like appearance of the face, owing to the carmine colouring, and the markedly pink condition of the whole body, I came to the conclusion that the body must have been exposed to a considerable percentage of carbon monoxide for some time after death had taken place.

One of the several points this accident demonstrates is that nothing will make up for a defective apparatus, no matter how skilled the rescue-man may be.

(*d*) *Punctured Bag.*—The rubber bag is protected by a stout canvas bag, and accidents caused by the bag being punctured during actual operations have never come to my notice Bags have frequently been punctured by the sharp ends of stick caustic, owing to careless handling whilst being cleaned. With regard to collapse of the bag, which frequently happens with other apparatus, this accident has never occurred with the Proto, owing to its design. In any case, it would have been prevented by the fact that our rescue-men make frequent use of the bye-pass.

(*e*) *Obstruction in Reducing-valve.*—This may be caused by a particle of the ebonite facing-disc becoming detached and choking the jet-orifice; or, very occasionally, by rust from the oxygen cylinder getting into the orifice. The supply of oxygen may become irregular owing to (*a*) the jet-orifice becoming partially obstructed, (*b*) the " carriage " sticking, and (*c*) the diaphragm becoming punctured.

This may take place unobserved by the wearer; the only guide is the cessation of the sound made by the oxygen escaping from the supply-tube into the bag. Difficulty of breathing is not always experienced, and should not be waited for as an indication.

The following is an account of an accident due to trouble with the reducing-valve:—

A man was wearing apparatus for the first time. When the apparatus was put on, the gauge showed a pressure of 105 atmospheres. The pressure in the apparatus was observed to drop abnormally at first. After an hour's practice, the wearer was noticed to stumble and fall. On examination of the apparatus, it was found in good working order, with the exception of the reducing-valve, which at a pressure of 20 atmospheres was only passing 0·6 litre per minute. The valve was then examined, with the following results:—

At 120 atmospheres, the valve passed 2·6 litres.
„ 90 „ „ „ 2·6 „
„ 40 „ „ „ 2·0 „
„ 30 „ „ „ 1·2 „
„ 20 „ „ „ 0·9 „
„ 15 „ „ „ 0·6 „

Although it was found that the ebonite disc on the regulator was worn away by the nozzle, inasmuch as the valve passed 2·6 litres at 120 atmospheres and down to 0·6 litre at a pressure of 15 atmospheres, yet the fault lay either in the diaphragm spring or in the "carriage."

Caustic Soda.—Attention has already been drawn to the fact that in the Proto apparatus, absorption of carbon dioxide was defective, and that considerable discomfort was caused by the high temperature of the inspired air.

Generally the quality of the caustic soda supplied was good, but occasionally some of inferior quality was found. This had a dirty yellowish or creamy appearance, and only absorbed carbon dioxide efficiently for from 45 to 60 minutes. The wearers complained afterwards of headache and in several cases of sickness. Sticky bags were frequent when the absorbent was defective.

If kept in stock some time, the tins were apt to get punctured. If this occurred, or if the lids were insecurely fastened, it was found that the sticks of caustic soda were coated over. A considerable part of such soda will appear satisfactory, but after being used for about an hour it ceases to absorb carbon dioxide. There was the same trouble with the Salvus absorbent cartridges.

In order to economise in caustic soda, one of the mine-rescue schools put half the usual charge into the bags for preliminary practices, which consisted of walking round leisurely in the fresh air for 60 minutes. On the evening following the practice two officers and several other ranks suffered from severe headache and sickness. After this experience, the full charge was employed. When only half is used, there is too small a surface of caustic for carbon dioxide to be absorbed sufficiently quickly, with the result that it collects in the bag and causes these unpleasant after-effects of carbon-dioxide poisoning.

Dangers of Training in Cold Weather, owing to Decreased Absorption by Caustic Soda, etc.—During the winter of 1916, it was found necessary to draw the attention of companies to the dangers which are experienced during training in rescue-apparatus in cold weather. In the schools, the dangers were thoroughly appreciated.

During rescue operations by one company after an enemy camouflet, the rescue-men had a great deal of trouble with several sets of Proto apparatus, owing to the intense cold interfering with the absorption of carbon dioxide by caustic soda and rendering the mica valves immovable. The trouble disappeared after the apparatus had been in use for a short time, but until this occurred the men had great difficulty in breathing, and were almost overcome, and in consequence rescue operations were delayed. The following notice was sent to companies:—

> Owing to the fact that caustic soda in the presence of low temperatures does not absorb CO_2 with sufficient rapidity, a considerable number of cases have occurred where men, during the first few minutes after putting on Proto or Salvus sets, experienced great difficulty in breathing, amounting in many cases to actual distress and feeling of suffocation, and in a few cases to development of momentary loss of consciousness. Some of these cases were followed by headache and sickness.
>
> This difficulty with caustic soda is readily overcome by telling the men to warm the caustic soda by wearing the apparatus for a few minutes without putting on the nose-clip, when the warm breath will quickly raise the soda to the temperature necessary for efficient absorption of CO_2, and the chemical action will then do the rest.
>
> The entrance of moist air into the Salvus cartridge thorugh ill-fitting lids or punctured tins may also contribute in some cases to this difficulty.
>
> Another trouble met with in the cold weather is the mica valves of the Proto becoming frozen and rendered immovable. In this case also the warm breath generally quickly frees them.

Purity of Oxygen.—Cases of men being overcome, owing to the amount of oxygen in the breathing-bag dropping to a very low percentage from accumulation of nitrogen, have occurred at different times during training in the rescue-schools. All the accidents took place when the wearer was engaged in hard work and had failed to wash out his bag with oxygen. At one time I believe it was customary for the men to inflate the bag before putting on the nose-clips, and I am led to understand that this is still taught in some of the rescue-stations in England. It was noticed that accidents occurred most frequently in hot weather.

Assuming the capacity of the Proto apparatus to be 15 litres, the reducing-valve set to pass 1½ litres per minute, the oxygen consumption equal to the supply, and 60 per cent. of oxygen and 40 per cent. of nitrogen in the bag at the start—in 30 minutes the oxygen percentage will fall to 30, in 45 minutes to 15, and in 50 minutes there will be only 10 per cent. This low percentage of oxygen would produce loss of consciousness and in time death. As the bag does not become empty, the attention of the wearer is not attracted to the danger. If the oxygen consumption were temporarily in excess of 1½ litres per minute for even a short period, as when the wearer did harder work, the reduction of oxygen below the danger-point would, of course, be much more rapid.

In the autumn of 1916, the question of purity of oxygen was taken up with the French firm who were supplying it. Analyses had showed that the average purity supplied was 95·5 per cent., but that some cylinders showed as low as 91 per cent. It was pointed out that whatever percentage of purity was supplied, we should be informed what it was, in order that measures might be taken at the schools to protect against accidents due to rapid fall of oxygen percentage in the bag of the rescue-apparatus. We asked for oxygen of 99 per cent. purity. The firm declared that oxygen of 99 per cent. purity (although possible in a laboratory) was not a commercial proposition, and that to raise the standard of purity by even 1 or 2 per cent. meant a great deal more time, labour, and expense, which they could not undertake. This firm refused to give any guarantee of purity.

In order to prevent accidents, the following order was circulated—in framing it, I took into consideration the possibility of getting oxygen as low as 90 per cent. purity:—

> "The quality of the oxygen available for use in rescue-apparatus has fallen off and the manufacturers are unable to guarantee a definite percentage of purity. It is possible that the percentage may drop below 92 per cent.
>
> "In view of this, in order to guard against accidents arising from accumulation of nitrogen in the bags, the following precautions must be adopted:—
>
> "For training in schools, all—
>
> "(1) Reducing valves to be set at 1¾-2 litres per minute.
>
> "(2) Bags to be flushed out with oxygen as soon as nose-clips are adjusted.
>
> "(3) The bags to be emptied through the relief-valve and filled with oxygen every 30 minutes.
>
> "(4) All reducing-valves sent to trenches to be set at 2 litres per minute."

This washing-out of the bag with oxygen at the start, with the use of the bye-pass if extra oxygen should be demanded, and regularly every half-hour, prevented accidents. Our experience has also proved that when the bag is washed out occasionally, the men can work harder and that no fatigue is afterwards felt. Waste of oxygen was not such a pressing problem in military mining as it is in colliery rescue-work, where, on account of the lengths of roads to be traversed, it is necessary to conserve the supply with the greatest care.

The Home Office "Memorandum on Schemes of Training and Practice"* relating to rescue-work states:—

> "Where oxygen breathing apparatus is used, care must be taken to ensure a high standard of purity in the oxygen used, and supplies, unless guaranteed by the manufacturers, should be tested by analysis. The Secretary of State is advised that it is not practicable entirely to exclude the presence of nitrogen, and that provided the nitrogen present does not exceed 2 per cent., the safety of the users of the apparatus will not be endangered. Oxygen containing a greater amount of nitrogen than 2 per cent., or any other impurity, would become a source of danger and could not be regarded as complying with the requirements of the Regulations."

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* See "Rescue Work," part i., *Mines and Quarries Form*, No. 72, February, 1915, page 3.

Makers' guarantees should be demanded. Until these guarantees are forthcoming, the only protection is to carry out the recommendations of the Mine Rescue-apparatus Research Committee, namely, to analyse the oxygen from every cylinder supplied for rescue-work.

Rusting of Oxygen Cylinders.—A certain amount of water-vapour may be found in oxygen cylinders, as a result of storing the oxygen in contact with water in the gasometer, or owing to bad working of the condenser. When the gas cools, this water-vapour condenses. Other causes of water appearing in the cylinder are: (1) if the baffle is dirty or misplaced (it is fastened down with a stud), water may come through from the pump; and (2) if the oxygen from the storage cylinders is rushed through too quickly immediately after the twin cylinders have been put on.

A number of Proto twin cylinders had to be discarded owing to rust developing inside. The presence of rust leads to a slowing down of the delivery of oxygen, or the connexion between the two cylinders becomes occluded. As a result of rusting, it was sometimes found that when cylinders were charged the pressure-gauge showed 120 atmospheres, but in a short time this dropped to 70. If particles of rust are carried into the reducing-valve from the cylinder, the orifice of the valve may be choked and the flow of oxygen interrupted.

The Mine Rescue-apparatus Research Committee have recommended that all cylinders of oxygen after being annealed should be scoured inside to remove oxide, and then given a coat of a special varnish to prevent rusting. The varnish, which is composed of gum-shellac, venetian red, and methylated spirit, is inocuous, adheres well, and does not flake off.

Accidents owing to Nose-clip of Apparatus Slipping off or being Detached.—An efficient nose-clip for the Proto is urgently needed. It should be light, easily applied, and attached to the headdress in such a way that it cannot be easily displaced.

A large number of nose-clips of different patterns were tried in the schools—spring, screw, ratchet, and one attached to a frame-like spectacles. All were liable to slip off, and most of them were uncomfortable to wear. The screw pattern was abandoned, and we generally finished the trials by continuing to use the original spring pattern, which we found the most satisfactory.

In hot weather and in arduous work, considerable difficulty was experienced in preventing the nose-clip from slipping off. During rescue operations, accidents happened owing to the nose-clip being accidentally detached or pulled off during the removal of a struggling gassed man. The cord attachment facilitated this, and is a decided drawback. We tried making the nose-clip more secure by having a nosebag attached by tapes round the head, but this arrangement never became popular.

A new type of headdress, to which the nose-clip is attached by straps, was recently sent to me by Dr. Briggs of the Mine Rescue-apparatus Research Committee. This was thoroughly tested by one of our instructors, who thought the arrangement was in some respects a decided improvement. The nose-clip is so attached that it cannot be pulled off, but it is of a wretched pattern—the screw type that we have discarded. Instead of four straps, as in the ordinary Proto headdess, there are six in contact with the face, but this disadvantage is counterbalanced by the comfort and freedom given to the movements of the head, owing to the elastic bands. I am quite sure that this headdress and nose-clip arrangement is capable of considerable improvement and may solve the difficulty we have so long experienced.

Rescue-work in Masks and Goggles.—At the discussion in Edinburgh in February, 1919, on the "Digest of the *First Report of the Mine Rescue-apparatus Committee*,"* some members thought it a great pity that we had not a face-mask that would be efficient and safe. Before describing a modified form of Proto and Salvus, where the mask of the box-respirator was used, let me make a few remarks on the dangers and drawbacks in the use of helmets and face-masks with apparatus.

In the ordinary mine-rescue work in the trenches they were never used, because I considered them unnecessary, objectionable, and having serious drawbacks—for example, the grave risk of carbon dioxide collecting in helmets. Half-masks are not so objectionable, but owing to the great difficulty in fitting them properly locally and making them airtight, there is the risk of leakage. Another important point is that vision is interfered with. If the field of vision should not be sufficiently extensive, travelling becomes slower, the work of the rescuer is greatly impeded, and he may do serious damage to himself or to the apparatus. All the eye-pieces belonging to rescue-apparatus that I have examined afford poor vision. Until recently there was the greatest difficulty in getting goggles which permitted good vision and did not dim. This problem has now been solved, and the eye-pieces of the latest type of box-respirator, which was issued to the Army some time before the Armistice, permit of excellent vision and are not easily dimmed.

In fires, the asbestos hood and apron were worn with the Proto apparatus. The work of rescue in dense fumes is made very difficult, owing to the reduced vision, and there is the added danger that the sense of direction becomes dulled and even lost; these factors tend to lessen the confidence of the wearer. Some men who took part in rescue-work in dense fumes told me that they had not the haziest idea where they were. I have found from my own experiences that where vision is imperfect, as it so often is in underground work in goggles, one cannot rely upon one's estimate of distance and time, and this is the experience of others. While working in a box-respirator, I thought we had walked about a mile and taken about an hour to do it, whereas we had only gone about 800 yards, and this had taken twenty-five minutes. This shows the necessity of connecting members of a rescue-party by means of a rope, preferably white, which can be seen in defective light. Electric lights and torches give a poor light in smoke, but are better than oil-lamps.

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* *Trans. Inst. M.E.*, 1918-1919, vol. lvii., page 44.

Use of the Box-respirator Mask with Proto and Salvus Apparatus.—Occasionally the enemy placed lachrymatory bombs in the explosive charge, with the result that our galleries became flooded with gas of an extremely irritating character, which instantly blinded the men. In order to carry out rescue-work or mining operations in the presence of this gas, it was necessary to protect the eyes. As the goggles issued with the Proto apparatus gave no protection, the sponge-rubber goggles which had been issued to the Army were used, and afforded perfect protection until early in 1917, when it was discovered that in certain heavy concentrations of the new lachrymatory gases employed by the enemy the gas came through. To overcome this difficulty, in March, 1917, Lieut. E. C. Scott, the C.O. of one of the mine-rescue schools, fitted the mask of a box-respirator to the mouth-piece of the Salvus apparatus. The mask was fitted into the mouthpiece of the Salvus and the Proto apparatus (Figs. 3 and 4) in exactly the same way as it is fitted to the mouthpiece of the box-respirator, all mouthpiece straps being done away with.

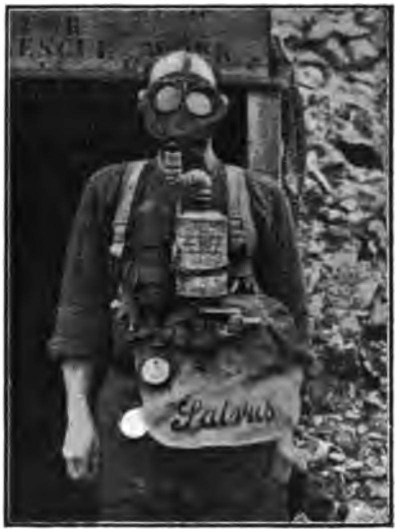

FIG. 3.—FACE-MASK FITTED TO MOUTHPIECE OF THE SALVUS APPARATUS.

This arrangement has the following advantages:—

(1) Goggles, mouthpiece, and nose-clip are all in one part, and are therefore fitted at one time to the face and cannot get lost.

(2) In the event of the nose-clip slipping off, the wearer

cannot inhale impure air through the nose before he has time to readjust it.

(3) The same remark applies to the mouthpiece, which can be partly removed for talking.

(4) Goggles can be cleaned without taking them off.

(5) In the event of a man becoming unconscious, he cannot breathe foul air.

The necessity of a perfectly-fitting mask is solved by each rescue-man having his own mask and adapter for fitting to the Proto mouthpiece.

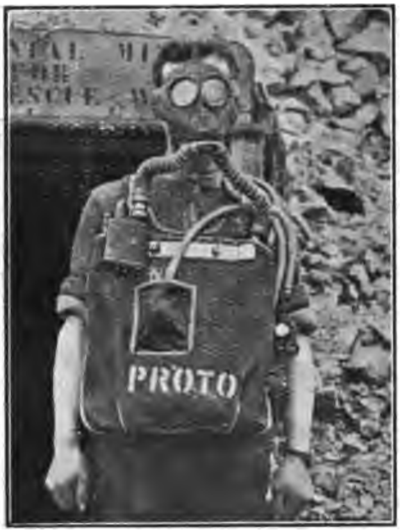

Fig. 4.—Face-mask fitted to Mouthpiece of Proto Apparatus.

This apparatus was used with excellent results in the presence of lachrymatory gas, and in very hot weather when the nose-clips are so liable to slip off. In ordinary work, of course, goggles are a distinct disadvantage and quite unnecessary, but in certain conditions, such as underground fires, as a protection against the fumes and against the risk of nose-clips slipping off, I am quite sure that this apparatus has a distinct sphere of usefulness.

It has been observed that when the nose-clip slips off, the man is apt to become flurried. One case of this kind took place in exploring a gallery full of smoke and fumes from a mobile charge, with the result that the man was slightly gassed. That the man had lost his nerve was evident by his statement that he had lost his nose-clip, which was found to be still attached to the apparatus.

II.—The Future of the Proto Apparatus.

(1) *Decrease in Weight by using War Office Light Pattern Oxygen Cylinders.*—When the question of supplying oxygen to airman flying at high altitudes was raised, the Air Board had to consider the possibility of reducing the weight of the oxygen cylinders. Their investigations proved that the weight of the cylinders was twice as much as it need be, and could be reduced with perfect safety.

All oxygen cylinders used in commerce must conform to certain Board-of-Trade regulations. They must be of a certain thickness, which varies according to the diameter. They must be annealed before being subjected to the hydraulic test, and again annealed at intervals of four years. Every year all cylinders are tested hydraulically to a pressure of 3,500 pounds per square inch, almost double the pressure to which oxygen is compressed in our country (120 atmospheres). In Germany the pressure is 140 atmosphere, and in one of the latest types of rescue-apparatus 150 atmospheres. With the present type of cylinders used, the margin of safety is obviously very large.

A special steel has been used by the Chesterfield Tube Company and the Metallic Seamless Tube Company in the manufacture of light cylinders, which have been successfully subjected to the Board-of-Trade tests. For some time past the Air Board have been using the light cylinders charged from 20 to 30 atmospheres more than formerly.

The twin cylinders at present used with the Proto apparatus weigh 17 pounds. With the light steel, one could be made to conform to the same hydraulic test and to weigh little more than 5½ pounds.

Instead of twin cylinders, one might be used. This would, of course, require to be of greater diameter and therefore greater thickness, and the point arises whether this would weigh more than light twin cylinders and their connexions. The twin cylinders fit into the back; they are very comfortable to carry, and possibly thus have an advantage over the single cylinder. If a single cylinder were adopted, it should be the same length as the twin cylinders; if longer, it would project at the sides, be in the way, and might lead to damage to apparatus. A lighter cylinder could also be used in the Novita oxygen reviving-apparatus.

In mine-rescue work the reduction of weight of the oxygen cylinders would be a very great advantage. Owing to the smaller weight to be carried, there should be an appreciable saving of oxygen; less oxygen being required by the wearer as less work was being done, the wearer and consequently the apparatus would be less hot; and there would be a decrease in the amount of carbon dioxide given off and a consequent saving of absorbent.

If the present difficulties in obtaining a more efficient absorbent of carbon dioxide are overcome, as appears likely, then by increasing the capacity of the cylinder and increasing the pressure in the cylinders by 20 atmospheres, the life of the Proto could be lengthened by at least an hour, at the same time reducing the weight of apparatus to about 10 pounds less than the original Proto.

In my opinion, this marked decrease in the weight of the oxygen cylinders is the most important improvement suggested, and will make the Proto apparatus a much more valuable and much more comfortable apparatus.

(2) *Methods for the Prevention of Overheating of the Absorbent.*—One of the chief defects of the Proto and other mine-rescue apparatus, except the Aerophor (liquid-air apparatus), is the fact that after an hour-and-a-half the inspired air begins to get hot. In ordinary temperatures this has never been sufficiently pronounced to interfere with work in the front line. In hot atmospheres, however, as, for example, in fighting fires and in very hot weather, this trouble appears much earlier and interferes with efficient work.

In order to abstract heat from the absorbent, Dr. J. S. Haldane proposed the use of three-compartment bags, in the back compartment of which was placed 4 pounds of sodium sulphate, while 5 pounds of caustic soda were used instead of 4 pounds. A large number of severe tests were carried out with this at the Second Army Mine-rescue School. These were successful, the sodium sulphate, by neutralizing the heat from the purifier, prevented the air from becoming warm. This method was then adopted for fighting fires, and a number of three-compartment bags were allotted to each army. The great objection to its use was that an apparatus already quite heavy enough for carrying out hard work was still further increased in weight. A few months after I discussed this question with Dr. Haldane and Dr. Briggs. Dr. Haldane told me his experience with sodium sulphate was that it was successful in preventing the air from becoming too hot, but that it was impossible to prevent the salt from getting into an anhydrous condition and changing its state. The great objection against its use was the increase in the weight of the apparatus. Dr. Briggs has carried out experiments with crystalized calcium chloride, which has the advantage over sodium sulphate that it does not change its state when heated, and can be used over and over again. Instead of a three-compartment bag, the ordinary Proto bag was used and a small bag, like a footwarmer, fitted with calcium chloride was placed amongst the caustic soda. From what I have heard of this method, I consider that it is a distinct advance on sodium sulphate. Major Henrici, Secretary of the R.E. Committee, made the suggestion that instead of one bag being filled with calcium chloride, a few small bags should be used. In this way there would be more equal distribution of the cooling agent.

About ten months ago, when visiting the Durham and Northumberland Fire- and Rescue-station at Newcastle-upon-Tyne in connexion with liquid-air apparatus, Mr. Mills informed me that he had carried out a large number of tests with the Aerophor, Meco, and Proto apparatus, using lime mixed with caustic soda. The lime, which must be of the best quality, with a high calcium-oxide content, is mixed with water and made into rolls, which are dried in an oven and broken up into small pieces.

4 pounds of caustic soda in Proto bag: temperature of absorbent at end of 2 hours ... ... 147° Fahr.
2 pounds of caustic soda and 2 pounds of lime: temperature of absorbent at end of 2 hours ... ... 138° Fahr.

In another test, in very hot moist air (61° Fahr. wet bulb), the temperature at the end of two hours, where caustic soda was used, was 180° Fahr., while with the above quantities of lime and caustic soda it was 140° Fahr.

Experiments with lime, which were carried out at one of the mine-rescue schools, proved satisfactory, after some preliminary difficulties in getting lime of proper quality.

(3) *Control of Oxygen Supply; Manipulation of Reducing-valves.*—The ideal apparatus would be one in which the rate of oxygen supply is automatically controlled by the wearer's breathing, adjusting itself with equal adaptability to demands during rest and violent exertion. This automatic flow was a feature of one English make of apparatus, the Weg, but it has proved a failure. I understand that in the American Gibbs apparatus a device of Dr. Haldane and Colonel Douglas has been adopted and has proved successful.

The consumption of oxygen varies very greatly, according to the amount of work done, etc., by the wearer. At rest, about 250 cubic centimetres of oxygen per minute will be consumed; walking at a slow rate, 1,200 cubic centimetres; quick walking, 2,000 to 2,500 cubic centimetres; and violent exertion, 3,000 cubic centimetres. This shows the wide variations which have to be provided for.

One of the great objections to apparatus like the Proto is that the oxygen supply is set at a fixed quantity. The objections to this are:—

(*a*) The breathing-bag is constantly overfilled when the wearer is not exerting himself. This is remedied by the blow-off valve, which in some apparatus is automatic, but in the Proto is not.

(*b*) During a period of rest or moderate exertion from two-thirds to three-quarters of oxygen are wasted, and the life of the apparatus is shortened.

For work in the trenches, the reducing-valve has always been set to give 2 to 2½ litres per minute. This is the amount used when walking at 4 to 4½ miles an hour. It should be added that more oxygen is used when walking at a sharp pace than during violent exertion with the arms and shoulders while the wearer is standing. The waste of oxygen was undoubtedly considerable, but while our men were wearing apparatus they were always doing a great deal of work. The frequent washing-out of the bag with oxygen had certainly the very beneficial effect of keeping the air cool.

This loss, however, was of such importance in colliery mine-rescue work, where rescue-men may have considerable periods in which they are either resting or doing light work, that Dr. Haldane advised the adoption of a reducing-valve which could be manipulated to suit the needs of the wearer. When I visited Messrs. Siebe, Gorman, & Company's works, I saw one of these valves which could be set at 0·6 litre per minute, which was the quantity required for a man resting, and at 1, 1·5, 2·0, 3·0, and 3·5 litres per minute, depending upon the demand. This undoubtedly results in an important saving of oxygen.

I believe that at home accidents have already taken place owing to men forgetting to alter the rate of supply when they began to work.

I did not advise the adoption of this modified reducing-valve for mine-rescue work in mines and in fighting fires in dugouts, for three reasons:—

(a) The danger of the men forgetting to alter the valve.

(b) The fact that when our mine-rescue men are called on to do work it is generally of a fairly strenuous character, so that the supply of 2½ litres a minute is not excessive.

(c) In military mining there is not the same necessity for economising oxygen, as the roads to be traversed are much shorter than in collieries.

(4) *Adoption of New Type of Valves.*—This question has already been discussed.

Conclusions.—There can be little doubt that the above modifications will result in a much improved apparatus. The advantages gained will be:—

(1) Decrease in weight—probably a clear gain of nearly 10 pounds.

(2) Coolness of breathing, even in hot atmospheres, owing to improved purifier.

(3) Longer life.

The adoption of an improved valve has also added to the efficiency of the apparatus.

The principle of liquid air could be applied to the Proto, but after careful enquiry I am unable to see how it would confer any advantages, apart from the cooling effect of the liquid air or oxygen on the apparatus, and it has certain disadvantages.

The Proto is decidedly the simplest apparatus that has yet been invented, and the most foolproof. These are most valuable qualities for work in the trenches.

The President (Mr. G. Blake Walker): These are two of the most interesting papers that have been read before the Institution. It is not quite the same sort of work as that carried out in mines that has been done during the last few years at the front, but the conditions have been such as to give mine rescue-apparatus a much more thorough test than has ever been possible hitherto. We cannot admire sufficiently the courage which has been displayed by the men who have been carrying out such arduous work in connexion with rescue-apparatus. These men naturally thought when they went to the front that they would be engaged as infantrymen, and that a large part of their work would consist of actual drill and the use of firearms; but the difficulties with which they had to contend in the presence of noxious gases in confined places like mines were much more arduous and terrifying than those of which they had previously had any experience.

We are now, it is hoped, on the eve of obtaining a peace with the enemy, and we will have to review the circumstances of the war as a thing of the past; but we have not yet acquired all the lessons which may be derived from it. A great many of the experiences which have been described may be more or less imitated in actual mining operations in this country, and we hope that any improvement in the design of the apparatus that experience has shown to be necessary will be introduced for the benefit of the mining world.

To some extent we have been playing with the problem in comparison with the work which had to be done at the front. I hope that the discussion on the papers will not by any means be confined to this meeting, but that at the different meetings of the Federated Institutes throughout the country they will be studied by those who have had, and are still having, to carry out rescue-work, and that we may all learn many useful lessons from the experience of the Army.

Mr. G. F. F. Eagar (Madeley, Salop): The work done by the Tunnelling Companies in the prolonged trench warfare on the western front in France and in Flanders, and also in the Dardanelles, is known to most of those present, since many of the members of this Institution took part in the actual operations. The general public, however, knows very little of the magnitude of the work involved in the enormous mining and dugout schemes which a prolonged warfare of positions necessitated. Colonel Logan's papers will therefore assist very greatly in giving the mining world a fuller realization of the part played by mining engineers and miners in enabling our front-line trenches to be held against an enemy who started the war, equipped to the last degree, and against whom for many months only extemporized means of defence were possible. In many parts of the front our mining was started after the enemy had commenced his operations, and the development of an adequate defence under such conditions was a matter of extreme difficulty and danger. At that time the enemy had to be felt for, and in many cases he could only be made to disclose his position by our "bumping" into his mines and galleries, often with deadly results to the personnel engaged in the mining operations at that moment.

These are a few points in Colonel Logan's papers to which I would like to refer before attempting to draw any conclusions or applying the lessons learnt from mining in warfare to peaceful mining at home.

The training of officers and men was of a most searching character. Absolute familiarity with all parts of apparatus—Proto, Salvus, and Novita—was insisted on, and the practical work was made to resemble as much as possible the precise conditions which would be met with in the trenches. All ranks were first familiarized with the apparatus by handling it in parts and by wearing it whilst walking about in the open; they then practised working as a team with signals; all subsequent practices were begun by ladder-climbing, obstructions such as might be met with in small shafts being placed on the ladders; the training galleries were for the most part 4 feet 3 inches high and 2 feet 3 inches wide. After the first few practices, the galleries were filled with dense sulphur fumes, lachrymatory gas, smoke from smoke-bombs, etc.; and all men had to practise traversing galleries of great length under these conditions, doing such work as building sandbag-stoppings, tamping up charges, getting dummies out on the mine stretcher, etc., each practice finishing with a further spell of ladder-climbing. The work was graduated and increased each day, and the final test was downright hard work. All work of charging, assembling, washing, etc., was done by the teams under the supervision of the training staff, and all ranks were submitted to a searching examination on the assembling, charging, etc.. of apparaus. It was considered of first importance that the men should have not only a thorough grounding in the practical use of portable breathing-apparatus, but also several hours' instruction on the causes and results of gas-poisoning. Special attention was devoted to the practice of artificial respiration: all ranks were taught how to examine gassed men for signs of life, and were told that if there were any sign of life in a patient they would be held responsible if he did not recover. The soundness of this method of training was splendidly exemplified repeatedly, as, for example, in the recovery of the two men mentioned by Colonel Logan; these men were given up as hopeless by the trench medical officers, but the Proto men found some signs of life, and by working on them in relays, with artificial respiration and the administration of oxygen, the men recovered completely.

With reference to the dangers of wearing portable breathing-apparatus during the very cold weather experienced in the winter of 1916-1917, it was stated as a result of a recent test carried out in a cold chamber in London, at a temperature of $-30°$ Fahr., that the Proto apparatus can be used successfully at very low temperatures. Inasmuch, however, as men experience serious discomfort until the apparatus is thoroughly warmed up, it would appear to be highly inadvisable to attempt its use under such conditions: a man requires to be thoroughly fit before attempting work when wearing self-contained breathing-apparatus, and a man who starts his work feeling uncomfortable or ill is likely to be a danger to himself and to others.

With regard to the rusting of oxygen cylinders, considerable experimental work is now being undertaken, and the question is receiving attention from several research bodies; there appears to be every reason to believe that the dangers and losses of efficiency due to this cause will soon be surmounted completely.

The nose-clip difficulty is a very real one. Of the various types we tried, the safest was the screw-clip; men, however, object to wearing this clip, because it is a little painful to use. The ratchet type and spring nose-clips attached to the apparatus by a light cord are comfortable, but are extremely dangerous, as they are very insecure. There is a real need for a nose-clip which cannot become detached as long as the mouthpiece is in position and is comfortable to wear whilst stopping the nostrils effectively.

The ideal portable breathing-apparatus of the future is far too big a problem to be enlarged on here, and, in any case, the matter is now in the hands of the Mine Rescue-apparatus Research Committee. War experience has provided an amount of valuable information, which it is hoped will be taken into full account by the Committee. Reduction in weight is of considerable importance, but true reliability, fool-proofness, and compactness are of even greater importance. What is wanted is an apparatus which a man can put on and never have to think about until his work is done. Colonel Logan refers to the type of cylinder evolved by the Air Ministry for use on aeroplanes (I should like to point out that the work of originating and developing the light cylinder was done entirely by the Air Board and Air Ministry, and not by the War Office). In these cylinders the weight in proportion to capacity has been cut down to a very low figure, but the factor of safety is too low to permit of their being used commercially; their elastic limit is very near their bursting pressure, the stress is very high, and their life in service is very short. However, the experience gained by the Air Ministry in this direction is of great value, and as that body is in close accord with the various committees who are now tackling the question of the production of light cylinders on a commercial basis, it is hoped that the problem will be solved completely in the near future.

With regard to the ideal reducing-valve for portable breathing-apparatus, the automatic or lung-governed valve is undoubtedly ideal, but practically this presents very great difficulties. The valve of Sir William Garforth's Weg apparatus is the nearest approach in this direction at the present time. The real trouble is that the sensitiveness of any such valve to minute variations of pressure in a closed circuit depends on having a very small working pressure on the low-pressure side of the valve or in the reducing-valve chamber, and such a low pressure results in the functioning and ultimate delivery from the valve being affected materially by the bottle pressure; the valve then tends to deliver an excessive volume when the cylinder is fully charged and too little when the cylinder is less than half full. In valves of the Endurance type, such as the one used on the Proto apparatus, the delivery is very little affected by the cylinder pressure, because the closing pressure of the reducing-valve is high, being about 75 pounds per square inch.

I would like to refer for a moment to the question of testing for the presence of carbon monoxide in mines. In France we had very considerable experience of testing with small birds and with mice; we also tried a special type of palladium-chloride detector, evolved by Major Jones, D.S.O., of the Central Laboratories, G.H.Q. This palladium-chloride detector differed from the ordinary type in that the alkalined paper was wetted with the special solution in the actual air to be tested, so that freshly-prepared test-papers were used in each test. The first form of this detector was too sensitive, the edge of the "blot" of moistened paper showing black in 60 seconds with an amount of carbon monoxide present of apparently less than 0·01 per cent. A later form was less sensitive and more practicable, but one could not be certain that there was no trace of other gases which might cause a blackening of the outer edge of the ring, and the appliance never came into general use.

With regard to the respective value of small birds and mice, I found mice perfectly satisfactory in every way; they are also much more easily manipulated. Birds vary very much in sensitiveness: they usually stand quite still on their perch until they begin to feel the effects of gas; they then move their heads about a little, ruffle their feathers, yawn, sometimes vomit a few seeds, straddle their legs on the perch, rock a little on the perch, and then collapse on the floor of the cage, with their wings outstretched. They are a nuisance to carry when wearing portable breathing-apparatus, and will not stand rough usage.

If the gas is at all strong, they generally die after an exposure, though I once gassed a canary six times in a night in air containing very small percentages of carbon monoxide, and brought him round each time.

I found that tame mice which have become accustomed to handling are the best to use. It is then an easy matter to put a few in a button-up pocket, and the drawback of having to carry a cage is thus avoided. The rapidity with which a small animal will show the effects of carbon-monoxide poisoning depends on the volume of the tainted air which it gets into its lungs; consequently, at the Second Army Mines Rescue School men were trained to take a mouse out of their pocket and make it climb over their hands, thus doing a considerable amount of work. A mouse used in this way will indicate the presence of carbon monoxide more quickly than a bird sitting motionless on its perch: it rapidly becomes sluggish in its movements, and soon loses the use of its legs. I have tried mice under these conditions against a bird sitting on a perch in a cage, and in very small percentages of carbon monoxide the mouse was helpless before the bird showed symptoms of distress.

The application of the lessons learnt in the training of a large mines-rescue personnel on active service in France to the problem of training for mines-rescue work in the coalfields of this country is not easy. The outstanding difference between the two problems is that on active service we had the pick of the coalfields under military discipline, working towards the elimination of dangers which were ever present. In this country, the call for mines-rescue brigades is, thank Heaven! much less frequent; by judicious propaganda, however, it should always be possible to maintain an equally high *esprit de corps.* This is really a matter of the maintenance of the existing splendid spirit amongst our mines-rescuers, for nothing can be worthier of higher praise than the *grande morale* of these men at the present time.

I think all who have a knowledge of the working conditions and the character of the work done in France will agree in attributing the splendid results obtained to the following points in the character of the training:—

(1) Careful selection of the men, as great attention being paid to their psychical as to their physical characteristics.

(2) Intensive training of a far more searching character than has hitherto been attempted.

(3) Insistence on a high standard of theoretical as well as of practical knowledge of all branches of their special duties.

(4) Close supervision of all phases of training at central rescue-stations and the subsidiary company rescue-stations.

(5) Special "refresher" courses of instruction, with graduated markings as men became more efficient.

(6) Cancellation of efficiency certificates of any men who showed evidence of a weariness of the work or of any falling-off from a high standard in actual emergencies.

(7) Recognition of all Proto men as worthy of special consideration.

(8) Most careful inspection of all gear, with a frequent return of apparatus to the Central Army School for complete overhaul.

Most of these points are already covered by the regulations under which training in portable breathing-apparatus is now carried out in this country; but I venture to suggest that, apart from the question of the provision of more perfect apparatus, even better results than have hitherto been attained would follow from development along the lines on which the excellent results referred to by Colonel Logan were achieved.

Dr. J. S. **HALDANE** (Oxford): I think it must be a great satisfaction to mining engineers that all the trouble which has been taken in regard to rescue-apparatus has borne such good and valuable fruit in the war. There are so many important points in the two papers that it is difficult to single out any in particular. I am tempted, however, to say a word or two about the mice and birds, referred to by Colonel Logan and Mr. Eagar. The first time that mice were introduced was at the Tylorstown explosion in 1895. Some gentleman of the press had reported that I was using mice, and the result was that I immediately got a friendly telegram from the Home Office to say that I had not a licence under the Vivisection Act for experiments at that particular colliery.

White mice and birds nevertheless gradually came into use by mining engineers; but the next trouble was that it was necessary to show miners and mining students how to test for carbon monoxide with a mouse or a bird. My friend Sir John Cadman wished to show this painless test to students, and applied for a licence under the Vivisection Act to do so, but was refused and told that he could not show the experiments. Government red tape had wound itself round canaries and mice for the time, and I had to cut it, and did so by giving a paper before The Institution of Mining Engineers and at three separate meetings of the Federated Institutes in different parts of the country, and by showing the whole of the experiments which were necessary in testing for carbon monoxide with mice and birds. I was not prosecuted, and there has been no more trouble in regard to the Vivisection Act.

These are instances of what everyone in this room knows so well—the unsatisfactory working of Government over-regulation. The Home Office is extremely friendly to scientific investigation, and to everything progressive in mining, but is tied by regulations, and there are people there whose duty it is to see that the utmost letter of each regulation is carried out. The coal-mining profession is rightly distrustful of Government control, and scientific men suffer from it under the Vivisection Act, the net result of which is great waste of time, money, and paper, with no benefit to animals.

A point to which I should also like to refer is the administration of oxygen. Colonel Logan has given an account of several experiences in this direction—in one case, of a man who was buried being kept alive by giving him oxygen. A short time ago that effect of oxygen would have seemed to me quite unintelligible. What good could oxygen do to such a man? There is plenty of oxygen in the ordinary air: why should pure oxygen sometimes have the effects which it does have? Well, I have been engaged in investigating that subject during the last year or two; and we now know that the administration of oxygen to patients in all sorts of conditions when there is nothing whatever the matter with the lungs themselves may be very important. The breathing has only to be shallow, and a man will be short of oxygen. For instance, if a man were jammed among sand, he could take only very shallow breaths of air and would die of asphyxiation; but if he took shallow breaths of oxygen, he would go on living all right, as has actually been found in the case which Colonel Logan has mentioned.

If one took a mine rescue-apparatus and let the bag get very nearly exhausted, so that one could not get a full breath of air out of it, and all one could do was to take a great number of small breaths, one would very soon find oneself in a state of asphyxiation; but if oxygen is in the bag, one goes on all right till the oxygen is exhausted. Very shallow breaths of oxygen will suffice, whereas with ordinary air the oxygen does not get down far enough into the lungs.

Sir WILLIAM GARFORTH (Pontefract): I am glad of this opportunity to congratulate Colonel Logan on his most instructive papers. I hope that when they are published we will take courage, and endeavour in every way to perfect mine rescue-apparatus. I think we have now arrived at the stage when we may ask how the apparatus can be further improved and how all the bad things which have been said about it can be dispelled. I suggest, therefore, that some kind of competition should be arranged at an early date, in order to see what can be done to improve it. There are rescue training galleries in different parts of the country, and a great number of men have been practising in them for some years past. The advantages which we now have, owing to the additional experience gained at the front, should be utilized, and I would suggest that the best way would be in the form of a competition. We are now trying to design an apparatus which, when completed, shall be the most perfect in the world and be called the "British" apparatus.

The lung-governed valve has been referred to, and I think that if we can get a reliable valve that can be governed by the lungs, it will be a step in the right direction. When it becomes known that there is nothing to be patented, but that everything is to be done for the benefit of the miners, then we shall make another attempt, such as Colonel Logan has mentioned has been done in France; and in another twelve months, with the help of the Home Office Committee, which I believe is quietly doing valuable work, I think that we will have the apparatus which many of us have been looking forward to for the last thirty or forty years.

Mr. M. H. **Mills** (Folkestone): I have been instrumental to a certain extent with the War Office in selecting men and officers for the Tunnelling Companies. Most of the young men who so gallantly volunteered to go out and who did such remarkably fine work have now come home, and I am sorry to hear that several, if not many of them, have not yet got appointments which are suitable for them. I hope that the Institution and its members will remember the great work they have done, and make some organized arrangement for seeing that all of these officers and men are suitably placed at as early a moment as possible.

Mr. **William Maurice** (Sheffield): It would be very valuable to colliery officials if they could be placed in possession of the procedure with regard to the courses of instruction which have been established during active service conditions. We have heard this morning of the courses of intensive training and the elaborate arrangements made to ensure that every user of rescue-apparatus had a perfectly intimate knowledge of the apparatus.. If these official regulations could be included in the *Transactions*, they would be very helpful to all engaged in the coal-mining industry.

Lieut.-Colonel **Logan**, D.S.O.: In 1915 I wrote a small pamphlet on gas-poisoning in mines, which was revised in 1916 and again in 1917. It gives a good deal of information regarding mine rescue-organization. It is a War Office publication and is quite accessible.*

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* *Memorandum on Gas Poisoning in Mines* [S.S. 308].

I think it is for one of the officers in charge of the mine-rescue schools—for example, Mr. Eager—to give the information asked for by Mr. Maurice. It would make a most useful paper if detailed information were given of the courses of instruction carried out, for example, in the Second Army Mine-rescue School.

Mr. EAGAR: I shall be very glad to do what I can to prepare such a paper as has been suggested.

Mr. C. C. ELLISON (Monckton Main): A large number of men must have been very efficiently trained in the use of rescue-apparatus, as these men must have had more practice than the rescue-teams at home are likely to receive. When such men return to the collieries, they ought to be a most valuable asset, and should become members of the home rescue-teams. Most of the members are probably aware that an association is being formed now by the members of rescue-brigades, with a view to the men getting so many more practices per annum, and those in charge of the rescue-stations have now to decide what is necessary and what is not. I think that if we could have Captain Eagar's paper at the September meeting of the Institution, and have a discussion on it, it would help us greatly in deciding how long it should take, and how many practices are necessary, to make a man efficient.

Dr. HENRY BRIGGS (Edinburgh) wrote: Colonel Logan has contributed two papers of very unequal value. His first paper is a most useful account of the great difficulties of rescue-work at the front during trench-warfare days; it is a narrative of the highest interest even to a wider public than the Institution provides, and in writing it Colonel Logan has contributed to the detailed history of the war a chapter which will be read with pleasure and pride as long as the *Transactions* are accessible. There can be no doubt that the success of the operations with rescue-apparatus was largely due to Colonel Logan's own energy and initiative, and to his ability in selecting the right men to take command of the training stations. The incalculable value of strict discipline is evident throughout, and is, in my view, the most useful of the lessons the author teaches. With discipline, as Colonel Logan shows, oxygen breathing-apparatus can be of great service in saving life and in allowing operations to be conducted in foul atmospheres which could not otherwise be attempted; while, without discipline, even the best apparatus of the kind must fail and lead to loss of life. How to promote and maintain the sense of discipline among those concerned with the use of these appliances in mines is the most important problem connected with mine-rescue work at the present day.

The second paper stands on a different plane. As so much of it deals with the same points as were raised in Mr. D. Penman's "Digest of the *First Report of the Mine Rescue-apparatus Research Committee*,"* it would perhaps be more correct to regard it as a contribution to the discussion of the latter rather than as a new paper. When viewed in that way, the accidents with Proto apparatus described by Colonel Logan are useful in bearing out much that was said in Mr. Penman's "Digest." The question of the design of the oxygen cocks, obstructions in the reducing-valve, the case of diminished flow through the reducing-valve, the purity of oxygen, the rusting of oxygen cylinders, and the use of masks and helmets—constituting most of the first part of the paper—will be found already to have received attention in the earlier paper and at the hands of those discussing it.

It is a little to be regretted that the author has not kept more in touch with the recent work of the Rescue Research Committee. So many of the points raised in the latter part of his paper have been worked on by the Committee that he is placed in much the position as the man who brings his horse to sell the day after the fair. For example, the Committee from the beginning have been engaged with the problem of getting a light and safe oxygen cylinder, and, with the assistance of the Technical Department of the Air Ministry and the Chesterfield Tube Company, have succeeded, I believe, in solving that problem by producing a cylinder 13 inches long and weighing a little over 7 pounds, with a capacity (at 120 atmospheres) slightly more than that of the double Proto cylinders. The new cylinders are designed to bear working pressures up to 150 atmospheres, and are tested to 225 atmospheres. The extremely light airman's cylinder alluded to by Colonel Logan has been found to have an insufficient margin of safety and to be otherwise unsuitable for rescue-apparatus purposes.

The method of placing a cooling substance—for example, hydrated sodium sulphate—in a few small bags, a suggestion attributed to Major Henrici, has been in operation at some mine rescue-stations for a considerable time. Lime mixed with caustic soda has been used for several years in Edinburgh, and in Proto bags by Mr. G. L. Brown, at Mansfield, Chesterfield, and Ilkeston.

The new headdress to which the author refers has been improved a great deal during the last few months, although there is no intention of abandoning the screw nose-clip in connexion with it. The ordinary screw-clip, discarded at the Army Proto schools for the spring-clip, easily falls off, but that difficulty is avoided by holding the clip in place by bands, and the modified clip, so held, remains in position even during profuse perspiration. A properly-padded screw-clip is the most comfortable form known. Comfort in this instance is part and parcel of security, for a harsh spring-clip becomes so intolerable to many people after a time that the temptation to slip it off for a rest can hardly be resisted. On the whole, then, there is something to be said for the "wretched" screw-clip in its new form, and, like an Army once termed "contemptible," it possesses the prime virtue of sticking on. The author approves of elastic bands to hold the nose-clip to the skull-cap, as allowing of greater freedom of movement. His approval on that ground would be justified only if the human being, like the elephant, were able to move his nose from side to side while keeping his scalp stationary.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 236.

In his second paper Colonel Logan errs here and there on questions of fact. For example, he alludes to certain Board-of-Trade regulations regarding oxygen cylinders. There are no such regulations. Early in the century a Commission made a number of recommendations, which are now obsolescent; but, although followed by the railway and shipping companies, they bear no legal weight. Again, he credits Drs. Haldane and Douglas with suggesting to Mr. W. E. Gibbs the automatic oxygen release which is associated with the latter's name, and is the subject of one of his patents.

Colonel Logan's first paper is so excellent that it is a pity that he should have followed it by one containing so much that is open to attack.

In his book on *Gas Poisoning in Mining and other Industries*, written in collaboration with Prof. John Glaister, Colonel Logan has dealt at some length (page 341 *et seq.*) with the absorption of carbon monoxide by dead bodies, and in his second paper he refers to that interesting phenomenon in describing a fatality at the front. The fact that a corpse may absorb carbon monoxide through the unbroken skin may in certain cases of death in mines—especially if the victim wore rescue-apparatus and lay a long time before being recovered—have an important medico-legal bearing. Assuming death from some other agency, it would be useful to know how long, approximately, a human body must remain in an atmosphere containing, say, 1 per cent. of carbon monoxide before the blood near the skin becomes sufficiently saturated with the gas to make it possible to mislead the ordinary observer as to the cause of death. It is also of importance to know whether cutaneous penetration by carbon monoxide has been observed on the living subject, and, if so, what rate of blood-saturation results therefrom.

Brigadier-General R. N. Harvey, C.B., C.M.G., D.S.O. (London) wrote: In his career before the war Colonel Logan was intimately associated with mine-rescue work and miners, but I venture to express the opinion that he never anticipated that his expert knowledge would be called on to deal with mine-rescue work under the conditions which obtained in the front trenches of Flanders and France.

I cannot criticize the paper, which I think is altogether admirable, and will only correct it in one minor point. At the Battle of Messines the trenches and dugouts were not cleared for 200 or 300 yards solely on account of the risk of gas-poisoning, but owing to the uncertainty of what would happen to these structures when the enormous charges were fired. We feared collapse, and the dugouts and trenches were evacuated so as to avoid casualties through men being buried as well as gassed.

Colonel Logan explains clearly the circumstances and difficulties attending mine-rescue work on active service, and gives telling examples of the results achieved by the high grade of efficiency produced by the training in the mine-rescue schools. Colonel Logan was primarily responsible for inculcating the desire for efficiency and for the consequent results. It was proved over and over again that a company well trained in mine-rescue work and strictly disciplined in taking precautions against mine-gas poisoning was always the most efficient company in the mining areas. It may be difficult to persuade men to leave their comrades whom they believe are gassed and could be saved, but we had so many cases of the gassing of one man causing the death of five or six other well-intentioned rescuers that the strictest orders on the subject had to be issued, and no heroic measures of trying to save men without proper precautions were countenanced.

I gladly acknowledge my debt of gratitude to Colonel Logan for his excellent work and unselfish and untiring efforts to establish mine-rescue work on the highest possible plane of efficiency. He is no theorist, but is a thorough master of the practical work as well as of the apparatus to the smallest detail, and by his close attention to the behaviour of the apparatus in all circumstances many important improvements were introduced that resulted in our outfit being the one which was known and proved to be the best.

Mr. H. MASON (Kidsgrove) wrote: Colonel Logan's reference to gas pouring from shafts into the trenches after the explosion of an enemy mine recalls to my mind an occasion when such gas was actually ignited. A section commander in our company was proceeding to investigate the result of an enemy mine explosion. At the entrance to the sap leading to one of the shafts was an overhead traverse, with a step down into this sap under the parapet. He stepped down with one foot and lit his candle, after which he remembered no more, except that there seemed to be a big flame " which felt very nice and warm." He was afterwards found lying gassed against the parados under this overhead traverse. On artificial respiration and oxygen being applied, he recovered.

MR. JAMES COOPER (Edinburgh) wrote: Having read Colonel Logan's interesting paper on structural defects or injury to the Proto apparatus and its future, it seems to me that with the splendid organization and the many opportunities of using breathing-apparatus in the war zone, greater benefits would have been gained if comparison had been possible with other types of apparatus—for example, the Meco and the liquid-air machines.

The author, in stating that the adoption of a lighter cylinder would increase the life of a charge from 2 to 3 hours, is faced with the great defect of the Proto—that is, the uncomfortable hot air from the breathing-bag after 1½ hours' hard work. He then mentions methods that have been tried to cool the air from the bag, and in summing up states that an improved purifier is required. Any improvement on the lines mentioned would, however, take away two important advantages of the present Proto apparatus—(*a*) its simplicity, and (*b*) its nicely-adjusted balance on the body. Any added weight to the bag, when the weight of the cylinders is to be reduced, will make the future Proto a badly-balanced machine, and at the same time would tend to produce a forward pulling force. It would also further distend the bag, and, in carrying out recent experiments at the Mansfield Rescue Station, Prof. McMillan, of Nottingham University, points out that the size of the Proto bag prevents to some extent the freedom of the arms; therefore further distension of the bag will aggravate this defect.

With reference to the hot air from the breathing-bag of a Proto apparatus, on page 17 of the *First Report of the Mine Rescue-apparatus Research Committee*, under the heading of " Requirement as to Temperature of Inspired Air," the Committee state that—

> " *The apparatus may fail owing to the Temperature of the Inspired Air becoming Excessive.*—The capacity for work is greatly reduced . . . by a high wet-bulb temperature. An apparatus should be regarded as unsatisfactory if . . . the inspired air exceeds 105°F. (40½°C.) under the temperature conditions commonly met with in the mine."

With the present method of purifying the air in the Proto, it will fail to pass the above standard, and this will tend to prejudice its future as a practicable rescue-apparatus. The effect of the improvements suggested in the paper would be to add 4 pounds or thereby to the weight of the bag on the front of the wearer and reduce the weight on the back from 17 to 5½ pounds, thus making the apparatus quite impracticable from want of balance. Does not the old aphorism, " the back is made for the burden," hold true with regard to breathing-apparatus? In my opinion, the method of purifying the air in the Proto is a greater defect than can be found in any one apparatus in use in this country. What appears to be required is the adoption of a light cylinder and a properly-constructed purifier in a sheet-steel case carried above the cylinder on the back of the wearer, with a distensible bag placed either between the shoulders or in front. The Tissot and the Gibb machines have all these three essentials placed behind, thus ensuring perfect freedom of the hands and arms. An adequate supply of cool and pure air for a period of at least two hours is essential in rescue-work, and the present Proto method of purification falls far short of this requirement.

FREDERICK P. MILLS (Newcastle-upon-Tyne) wrote: Colonel Logan's first paper shows how prompt obedience to orders and efficient supervision of rescue-work by the officers in charge enabled the work to be carried out rapidly and smoothly, and minimized the list of casualties. This confirms the necessity for strict discipline in mine-rescue work. Were the men engaged in mining in areas where camouflets were exploded provided with small birds or mice as a means of indicating the presence of poisonous gas? It would also be useful to know what methods of signalling were employed by the rescue-team in sending word out-bye, and how instructions were given amongst themselves when wearing apparatus. If Colonel Logan could give a diagrammatic sketch of the stretcher, it would prove useful. Reference is made to cases where fresh air was pumped by means of a " Holman " hand-pump. Could he also give some details of this pump?

Colonel Logan, in his second paper, not only records several interesting cases where accidents have happened due to defective apparatus, but mentions cases where accidents may happen. A great deal of the information contained in his paper is, of course, known to most rescue-station officials, and is also mentioned in the *First Report of the Mine Rescue-apparatus Research Committee*. With regard to accidents from loose joints in the Proto self-contained apparatus, the most common one is due to the reducing-valve block becoming loose where connected to the oxygen cylinders. I have found that the introduction of a small lock-nut on the screw before fixing on the reducing-valve block acts as an extra safeguard in preventing the reducing-valve block connexion from becoming loose owing to a knock. Mention is made in the paper that an accident may happen when the safety-hook spring is broken. Can Colonel Logan instance an actual case?

The main valve of the Proto oxygen cylinders is exceedingly bad in design, and it is gratifying to note that the makers have adopted the American Titan valve, as used in the Dræger apparatus. Cases are on record where the Titan Dræger apparatus has been in constant use for over six years without requiring any attention, whereas the present Fleuss valves need constant attention.

Cases in which the indiarubber breathing-bag is punctured are not uncommon, due to a sharp piece of caustic-soda stick protruding through the indiarubber bag, caused either by careless handling whilst cleaning or by movement of the bag when in actual use. I believe that caustic soda in ball form would overcome the liability to puncture. Frequently, due to rough handling during cleaning or to deterioration of the indiarubber, the central partition of the breathing-bag is split, thus allowing the exhaled air to pass to the intake side of the bag without coming into contact with the caustic soda.

Has Colonel Logan any actual cases of accidents happening to the reducing-valve due to the jet orifice becoming partly obstructed, the carriage sticking, or the diaphragm becoming punctured?

Precaution should be taken to ensure that the caustic soda is of high percentage purity, as during the war an inferior quality was produced in this country; when storing, care should be taken that the storage containers are thoroughly airtight. At the Durham and Northumberland Rescue Stations, when using the Fleuss apparatus, 4 pounds of caustic soda in stick form are used for practice purposes, and 5 pounds when on actual rescue-work.

The account of dangers of training in cold weather, owing to the decreased absorption of carbon dioxide by caustic soda, is very interesting, and the remedy appears to be quite satisfactory. It might be suggested that this difficulty would also be experienced when wearing the Aerophor liquid-air apparatus on account of the air coming from the pack being cold. During the early stages of wearing the apparatus, an excess of oxygenated air (70 to 80 per cent. of oxygen) is given off, resulting in nearly all the exhaled air escaping by the relief-valve. By the time that the amount given off has become reduced sufficiently to make it necessary to purify the exhaled air, the circulating system has warmed considerably.

During the war oxygen-supply companies in their endeavour to meet the urgent increased demand for supplies of oxygen only did so at the expense of a slightly reduced oxygen content. It would certainly be a distinct advantage if supply companies were pressed to give a guarantee of 98/99 per cent.

The remarks on flushing the bag occasionally by the use of the bye-pass will certainly minimize the risk of accidents due to low oxygen content.

With regard to accidents due to nose-clips slipping off or becoming detached, I drew attention some time ago to the usefulness of the new Army face-mask fitted to the Proto self-contained apparatus.* Colonel Logan mentions a case where the nose-clips of the rescuers were frequently knocked off whilst endeavouring to remove a struggling gassed man. Would it not be good practice to make such a man insensible by giving him a blow, similar to the method sometimes employed in rescuing a drowning man? In this way the rescue-party could carry out effectually the work without fear of the gassed man endangering their lives.

With respect to goggles, great difficulty has been experienced for some time in securing a pair of airtight goggles that will give a wide range of vision, will be comfortable and safe to wear, and will not be dimmed by perspiration. After considerable time and trouble, I have had designed for me a pair of goggles made by the Triplex Goggle, Mask & Lens Company. They are fitted with aluminium cases and are padded to fit closely to the eyes. They have the following advantages over many other types:—(1) A wide range of vision; (2) in the event of a blow on the goggles, there is no danger of the triplex glass damaging the person; (3) when working at a fire, the heat of the fire might splinter plain glass or other preparations, but will not affect triplex glass; and (4) they are comfortable to wear and are not easily dimmed by perspiration.

Colonel Logan is following out rescue-station practice in using white ropes as a means of guiding men in smoky atmospheres.

The light oxygen cylinders mentioned by him will certainly reduce the weight of the present Proto apparatus, and I am interested to know what the Rescue Research Committee have to say with regard to these cylinders in their coming Reports. I am doubtful whether Colonel Logan's statement is correct that an appreciable saving of oxygen would take place if the wearer carried several pounds less in weight. Would a 12-stone man be likely to consume more oxygen than an 11-stone man doing the same amount of work?

In fighting mine fires, a cool apparatus is very much appreciated by the wearer; but great care should always be taken that men with and without apparatus are withdrawn at frequent intervals when working in close proximity to underground fires on which water is being poured, on account of the humid state of the atmosphere, which, together with the high temperature, is liable to cause a rise in body-temperature and produce heatstroke.

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* See "Improvement in the Headdress of Breathing-apparatus," *Colliery Guardian*, March 8th, 1918, vol. cxv., page 494; and *Trans. Inst. M.E.*, 1918-1919, vol. lvii., page 150.

The prevention of over-heating of the absorbent and circulating air is certainly an important question in all mine-rescue apparatus, and one to which the Rescue-apparatus Research Committee should give particular attention.

With regard to the control of the oxygen supply, I object to a reducing-valve that can be manipulated to suit the wearer, similar to the one mentioned by Colonel Logan, which gives from 1 to 3·5 litres per minute, as accidents have happened owing to the person wearing it having omitted to make the alterations requisite to suit the amount of work he was doing. It is difficult for such a person to watch this point continuously when doing actual rescue-work. Probably someone could describe his experiences, or cite examples of accidents whilst wearing the Weg apparatus, as I believe a variable reducing-valve, similar to the above, was fitted to this apparatus at one time, but has since been abandoned. In my opinion, it would be a distinct advantage to have an automatic flow similar to that used in the American Gibbs apparatus.

I disagree entirely with Colonel Logan's statement that the Proto is decidedly the simplest apparatus and the most foolproof. Surely he has seen or heard of the Aerophor liquid-air apparatus, in which there are no valves to be manipulated by the wearer, and little or no attention is required during the time that the apparatus is worn. Would he not be inclined to think that this apparatus would be the most foolproof? I should like to have the views of other members on this point. Experiments are being pushed forward with the Aerophor liquid-air apparatus, and it is hoped that in the near future an efficient type of apparatus will be the outcome.

One important factor which is brought out in his paper is the importance of the officers in charge of rescue-stations being fully competent to undertake the work, as many accidents can be avoided when every care and supervision is taken. It is also very important that apparatus should pass approved tests in order to minimize structural defects.

Mr. G. J. Binns (Duffield): The President has said that these are two of the most interesting papers he has ever listened to. I would go a great deal further and say that they are *the* most interesting papers that I have heard read at any of our meetings for a great many years They introduce such a wonderful human element into the history, and add another leaf to the crown of martyrdom which the colliers have always willingly assumed. They break new ground for those who have been, so to speak, stuck with their noses to the pit-head for so many years, and I am sorry to think that at the time when these wonderful deeds happened we did not know something of them

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LIEUT.-COLONEL LOGAN, in reply, wrote: Before replying to some of the criticisms, let me say how pleased I was that one of the officers in charge of the Army Mine-rescue Schools was able to take part in the discussion. We were particularly fortunate in obtaining the services of men like Capt. G. F. F. Eagar, M.C., Lieut. R. C. Smart, M.C., Lieut. M. McCormick, Lieut. E. S. Scott, M.C., and Lieut. A. Penman. All these officers had skilled knowledge of rescue-apparatus and rescue-work in coal-mines, and, in addition, they had the great advantage of having been previously engaged in actual mining in the trenches, where two had gained the Military Cross; they therefore knew and appreciated the actual conditions under which the apparatus was used. All the officers were most enthusiastic in their duties, and most important work was carried out in the schools in connexion with improvements in apparatus and in the development of more effective methods of training. The efficiency of their work was reflected in the great success of the mine-rescue organization as a whole.

Dr. Briggs regrets that I have not kept more closely in touch with the recent work of the Mine Rescue-apparatus Research Committee. As I was describing rescue-work in France, I confined myself to the developments in connexion with mine rescue-apparatus and organization up to the time mining ceased; it is for Dr. Briggs and those who have been responsible for developments which have taken place since then to bring the records up to date. When I spoke of the future of the Proto apparatus, I only pointed to certain lines along which one might look for advancement. Probably if I had explained this and my reasons for writing the second paper, some of Dr. Briggs' criticisms would not have been necessary.

I always believe that we learn far more from our failures than from our successes, hence I deliberately described the accidents and troubles encountered while using rescue-apparatus in training and in the trenches. Naturally, my paper deals with many of the points raised in the Report of the Research Committee, but as active mining on the western front ceased in 1917, and much of the material for my article was taken from reports written in 1915 and 1916, I cannot agree with Dr. Briggs when he states that my second paper should be regarded as a contribution to the discussion of the Report of the Mine Rescue-apparatus Research Committee.

I have already called attention to the great value of the work of the Mine Rescue-apparatus Research Committee,* of which Dr. Briggs is a member, and the effect it is sure to have on the future of mine rescue-work. I neglected to mention, however, that in the early months of 1918, on the representation of Dr. Briggs, a very important arrangement was made with the Department of Scientific and Industrial Research for the Mine Rescue Committee to act as a Research Committee for problems arising in connexion with mine rescue-work in France.

Dr. Briggs has called attention to two statements in my second paper which he thinks err on questions of fact. In the first I find that I was in error in reference to certain Board-of-Trade regulations regarding oxygen cylinders. I was always under the impression that the recommendations made by the Committee appointed in 1903 to enquire into the causes of the explosion and the precautions required to ensure the safety of cylinders of compressed gas had been adopted, and that they were now regulations, as they were carried out by the manufacturers of oxygen cylinders and always enforced in connexion with railway transport. I have made further enquiry and I find that these recommendations are still followed, but, as Dr. Briggs states, they are recommendations only and can carry no legal weight.

Dr. Briggs holds I am in error in crediting Drs. Haldane and Douglas with suggesting to Mr. W. E. Gibbs the principal for the control of oxygen in the well-known American Gibbs apparatus. Dr. Haldane has already called my attention to this. My authority for that statement is Prof. Yandell Henderson. In his description of the Gibbs apparatus† the following appears:—" The device for the physiological control of the oxygen supply was worked out by Mr. Gibbs at the suggestion of the senior author of this report, who in turn drew the idea from an apparatus devised by Haldane and Douglas, for a different and entirely scientific purpose, during the Pikes Peak expedition. The device would not be feasible in mine rescue-apparatus except for the extreme delicacy of response and the reliability of the Gibbs reducing valve."

In my second paper I described a case‡ where absorption of carbon monoxide by the skin after death had occurred, and Dr. Briggs, commenting on this, calls attention to the important medico-legal questions that might arise when, for example, the victim had worn rescue-apparatus and a long period had elapsed before the body was recovered. A number of cases of this phenomenon have already been recorded,* and in a few bodies I examined at the front, where there had been prolonged exposure to large concentrations of carbon monoxide in the mines, I demonstrated to my own satisfaction that there had been considerable absorption of carbon monoxide by the exposed surfaces of the skin and mucous membrane. In one post-mortem examination I was able to substantiate the findings of Strassman and Schultz† and others, that in bodies which have been exposed to carbon monoxide for some time the blood of the anterior part of the liver contained a larger carbon-monoxide saturation than the blood of the posterior part. A very important point then in the proof that death was caused by absorption of carbon monoxide by the lungs is the equal distribution of carbon monoxide in the blood, and the amount of saturation. The fact that carbon monoxide is found in the heart and in the principal blood-vessels only shows, of course, that the person has breathed for a certain time an atmosphere containing carbon monoxide and that death may have been caused by violence.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvii., page 44.

† "Oxygen Mine Rescue Apparatus and Physiological Effects on Users," by Yandell Henderson and James W. Paul, Bureau of Mines, Canada, *Technical Paper 82*, page 21.

‡ *Trans. Inst. M. E.*, 1918-1919, vol. lvii., page 227.

Mr. F. P. Mills thinks that I have forgotten the Aerophor liquid-air apparatus. I am sure that he remembers my visit to his station at Newcastle-upon-Tyne in February, 1918, when I had been sent to England to enquire into the possibilities of liquid oxygen as an explosive (the Germans were using it in making dugouts and in demolition work), for use in welding, and in mine rescue-work.

The improved Aerophor is the lightest and coolest mine rescue-apparatus on the market. Even at the end of two hours' work it is quite cool. It is also a very simple apparatus, having few valves. Certain minor improvements were necessary on the type I saw, and probably some of these have now been carried out, namely: (1) the apparatus was clumsy (this fault could be easily rectified); (2) the tubes were much too small for hard work; and (3) the blow-off valve was set at 6 inches of water-gauge, which should be reduced to 3 inches.

I found, however, that there were other and much more serious drawbacks to the adoption of a liquid-air apparatus, as under:—

(1) The great difficulty in obtaining supplies of liquid oxygen, as the demand was far in excess of the supply. Mr. Mills told me that he had had great trouble with his two plants. These were of poor type and not nearly so reliable as some of the new plant, and consequently, sets of Proto apparatus were kept in the station in case of emergency. When we have an unlimited supply of oxygen, as the Germans have, this difficulty will disappear.

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* *Gas Poisoning in Mining and Other Industries*, by John Glaister and David Dale Logan, 1914, page 344.

† *Untersuchungen zur Kohlenoxydvergiftung*, by Strassman and Schultze, *Berliner Klinische Wochenschrift*, 1904, page 1233.

(2) Even with the recent type of container adopted by the Royal Air Force, which is much superior to the ones I saw in Newcastle, the loss of air averages more than 5 per cent. in the 24 hours. The source of supply, therefore, must be easily accessible. This was a serious drawback to the employment of liquid-air apparatus in the trenches.

(3) The rate of evaporation of liquid-air is not easily controlled and is affected by various conditions. This difficulty in efficiently regulating the supply is a serious drawback.

The difficulty of gauging how much liquid-air is available at any moment has been overcome, I believe, by the Technical Department of the Air Board.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM JUNE 29TH TO AUGUST 2ND, 1919, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of Week	Day of Month.	Magnetic character.	Intervals in hours (Greenwich mean time). 0h. to 2h.	2h. to 4h.	4h. to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
	June		14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
Sun. ..	29	0	35′·5	35′·5	36′·0	34′·5	37′·0	43′·5	51′·5	51′·0	46′·5	42′·0	40′·5	40′·5	41′·0
Mon. ...	30	0	41·0	39·5	37·5	34·5	35·5	42·5	48·0	48·0	44·5	42·0	40·5	40·0	41·0
	July														
Tues. ..	1	0	39·5	38·5	35·5	34·0	34·5	40·5	47·0	47·5	46·0	43·5	41·5	40·0	40·3
Wed. ..	2	0	37·5	36·5	34·5	32·5	33·5	39·5	46·5	46·5	42·0	41·0	41·0	40·5	39·5
Thur. ..	3	0	39·5	38·0	39·0	35·0	36·0	43·0	46·5	45·5	42·0	40·5	40·5	40·5	40·5
Fri. ..	4	0	40·0	38·5	37·5	35·0	35·5	40·0	45·5	46·0	43·5	41·5	41·0	40·5	40·5
Sat. ..	5	0	38·5	39·0	38·0	35·5	35·5	40·0	44·0	44·5	42·5	40·5	40·0	40·0	40·0
Sun. ...	6	0	40·0	39·0	38·0	35·0	34·5	38·5	46·0	46·5	43·5	41·0	40·5	40·5	40·0
Mon. ...	7	0	40·0	39·5	37·0	33·5	35·0	41·5	46·5	47·5	45·5	43·5	40·0	39·5	41·0
Tues. ...	8	1	39·5	35·0	32·0	32·0	35·5	42·5	49·0	51·0	44·5	42·5	41·0	37·5	40·0
Wed. ...	9	1	38·5	37·5	36·5	35·0	38·0	45·5	48·5	47·0	44·0	42·0	41·0	38·0	41·0
Thur. ...	10	0	38·5	39·0	37·0	35·5	37·0	41·5	47·0	47·0	43·5	41·0	40·5	40·5	40·5
Fri. ...	11	0	39·5	40·0	37·0	35·0	35·0	40·5	45·5	46·0	42·5	41·0	40·0	40·5	40·0
Sat. ...	12	0	39·5	39·5	38·0	35·5	37·5	43·0	47·5	47·5	43·5	40·0	40·5	40·0	41·0
Sun. ..	13	0	39·5	38·5	35·5	36·0	37·5	43·0	48·0	47·0	44·0	41·0	39·5	39·0	41·0
Mon. ...	14	0	39·5	38·5	36·5	36·0	37·0	41·5	44·0	44·5	42·5	40·5	40·0	40·0	40·0
Tues. ...	15	0	40·0	40·5	38·0	35·5	36·0	41·0	45·5	46·5	42·5	40·0	40·5	40·5	40·5
Wed. ...	16	0	40·5	39·0	37·0	35·0	36·5	43·5	48·5	47·5	44·0	42·0	41·5	40·0	41·0
Thur. ...	17	1	39·5	38·5	38·5	38·0	36·0	41·0	48·0	51·0	50·5	44·0	39·5	38·0	42·0
Fri. ...	18	1	40·5	41·0	36·0	34·5	35·5	41·0	47·0	47·0	42·5	40·0	40·5	40·0	40·5
Sat. ...	19	0	37·5	37·0	36·0	35·5	36·0	39·0	44·0	45·5	43·0	40·5	38·5	34·5	39·0
Sun. ...	20	0	34·5	36·0	35·5	34·5	37·0	41·0	45·5	47·5	45·5	42·5	40·0	39·0	40·0
Mon. ...	21	0	37·5	37·0	35·0	35·0	37·0	39·5	43·0	43·5	42·0	41·0	39·5	37·5	39·0
Tues. ...	22	1	37·0	38·5	36·0	32·5	35·0	42·0	47·5	48·0	47·0	45·5	41·5	41·0	41·0
Wed. ..	23	1	37·0	38·5	42·5	37·0	39·0	44·5	49·5	47·5	42·5	40·5	40·0	38·0	41·5
Thur. ..	24	0	38·0	38·5	34·0	33·5	36·5	42·0	46·0	45·0	43·0	40·5	40·0	39·5	39·5
Fri. ...	25	0	40·0	40·5	37·0	36·0	36·5	39·5	45·0	45·5	41·5	41·0	40·0	40·5	40·0
Sat. ...	26	0	40·5	39·0	36·0	34·0	36·0	44·0	50·0	47·0	40·0	39·0	40·0	40·0	40·5
Sun. ..	27	0	40·0	39·0	37·0	37·5	40·0	46·0	49·5	48·5	43·0	41·0	40·5	40·5	42·0
Mon. ...	28	0	39·5	38·5	36·5	34·0	36·5	43·0	48·0	47·5	43·0	40·5	40·5	40·5	40·5
Tues. ...	29	0	40·5	38·5	35·5	34·0	36·5	43·5	47·5	46·5	44·5	42·0	41·5	40·5	41·0
Wed. ...	30	0	37·0	37·5	36·0	35·5	37·5	42·0	46·0	46·5	44·0	42·0	41·0	40·5	40·5
Thur. ...	31	0	39·0	39·0	37·0	36·5	37·0	43·5	—	—	—	40·5	39·5	40·0	—*
	August														
Fri. ..	1	1	40·0	40·5	37·5	36·5	37·5	40·5	45·0	46·0	41·5	41·5	42·5	40·5	41·0
Sat. ...	2	1	36·0	35·5	36·5	36·5	36·5	39·5	44·5	46·5	45·0	42·0	39·0	39·0	39·5

Diurnal Inequality (*i.e.*, *departure from mean value for day*).

	1h.	2h.	3h.	4h.	5h.	6h	7h.	8h.	9h.	10h.	11h.	12h.
July, 1918	−1′·1	−1′·3	−2′·0	−2′·7	−3′·9	−5′·2	−5′·2	−4′·7	−3′·4	−1′·1	+2′·1	+4′·9
June, 1919	−1·9	−2·1	−2·0	−2·9	−4·4	−5·8	−6·4	−5·8	−4·0	−1·2	+2·2	+5·3
June, 1918	−0·8	−1·0	−1·6	−2·8	−4·0	−4·9	−5·2	−5·1	−3·9	−1·3	+2·5	+4·9

	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
July, 1918	+6′·3	+6′·5	+5′·6	+4′·2	+2′·5	+1′·2	+0′·1	−0′·4	−0′·3	−0′·5	−0′·7	−0′·9
June, 1919	+7·1	+7·5	+6·5	+5·0	+3·3	+1·7	+0·7	+0·3	−0·1	−0·5	−1·0	−1·5
June, 1918	+6·4	+6·4	+5·3	+3·5	+1·7	+0·7	0·0	−0·1	+0·1	+0·1	−0·4	−0·8

Mean Value for Month.

July, 1918.	June, 1919.	June, 1918.
14° 50′·4.	14° 41′·0.	14° 51′·2.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G.M.T.

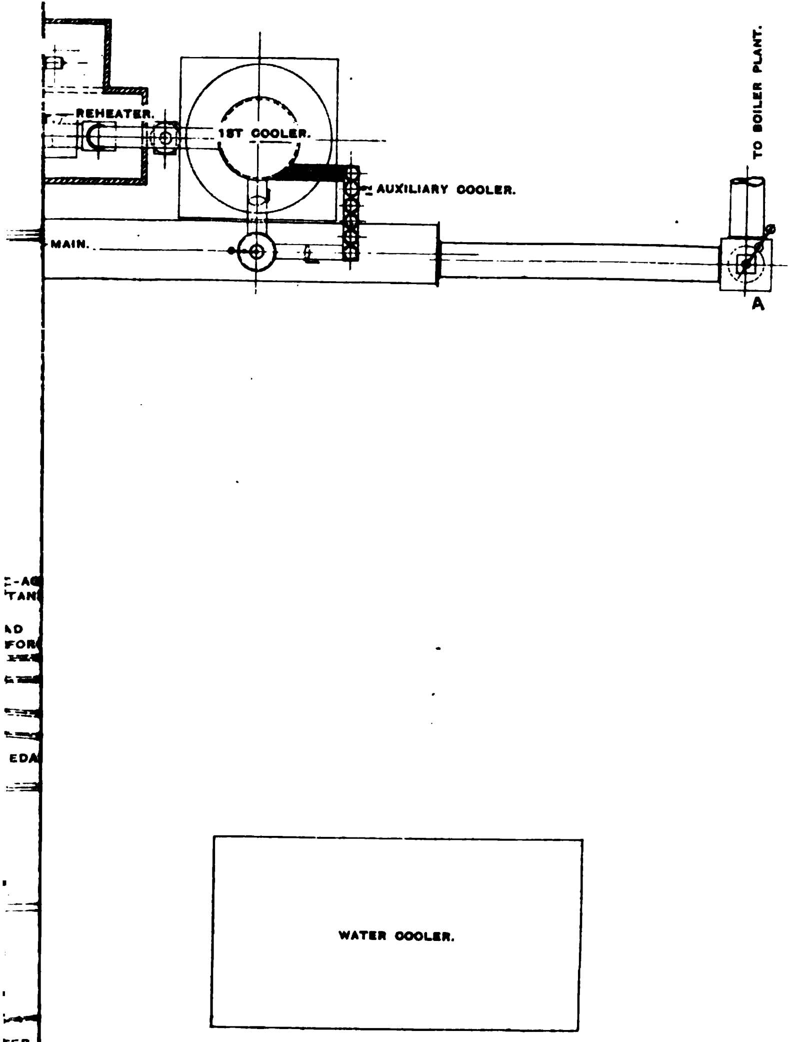
Character "0" means a day wholly free from any but small disturbances.

" "1" " " part or all of which is moderately or considerably disturbed.

" "2" " " part or all of which is highly disturbed.

* Owing to loss of trace between 12h. and 18h., some data are lacking for July 31st.

OUT OF No. 2 POWER PLANT.


REHEATER.
1ST COOLER.
AUXILIARY COOLER.
MAIN.
TO BOILER PLANT.
A
WATER COOLER.
-AG
TAN
AD
FOR
EDA
TER

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM JUNE 29TH TO AUGUST 2ND, 1919, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of		Magnetic character.	Intervals in hours (Greenwich mean time).												
Week	Month.		0h. to 2h.	2h. to 4h.	4h. to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
			14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
	June														
Sun. ..	29	0	35′·5	35′·5	36′·0	34′·5	37′·0	43′·5	51′·5	51′·0	46′·5	42′·0	40′·5	40′·5	41′·0
Mon. ...	30	0	[illegible]	39·5	37·5	34·5	35·5	42·5	48·0	48·0	44·5	42·0	40·5	40·0	41·0
	July														
Tues. ..	1	0	39·5	38·5	35·5	34·0	34·5	40·5	47·0	47·5	46·0	43·5	41·5	40·0	40·5
Wed. ...	2	0	37·5	36·5	34·5	32·5	33·5	39·5	46·5	46·5	42·0	41·0	41·0	40·5	39·5
Thur. ..	3	0	39·5	38·0	39·0	35·0	36·0	43·0	46·5	45·5	42·0	40·5	40·5	40·5	40·5
Fri. ..	4	0	40·0	38·5	37·5	35·0	35·5	40·0	45·5	46·0	43·5	41·5	41·0	40·5	40·5
Sat. ..	5	0	38·5	39·0	38·0	35·5	35·5	40·0	44·0	44·5	42·5	40·5	40·0	40·0	40·0
Sun. ...	6	0	40·0	39·0	38·0	35·0	34·5	38·5	46·0	46·5	43·5	41·0	40·5	40·5	40·0
Mon. ...	7	0	40·0	49·5	37·0	33·5	35·0	41·5	46·5	47·5	45·5	43·5	40·0	39·5	41·0
Tues. ...	8	1	39·5	35·0	32·0	32·0	33·5	42·5	49·0	51·0	44·5	42·5	41·0	37·5	40·0
Wed. ...	9	1	38·5	37·5	36·5	35·0	38·0	45·5	48·5	47·0	44·0	42·0	41·0	38·0	41·0
Thur. ..	10	0	32·5	39·0	37·0	35·5	37·0	41·5	47·0	47·0	43·5	41·0	40·5	40·5	40·5
Fri. ...	11	0	39·5	40·0	37·0	35·0	35·0	40·5	45·5	46·0	42·5	41·0	40·0	40·5	40·0
Sat. ...	12	0	39·5	39·5	48·0	35·5	37·5	43·0	47·5	47·5	43·5	40·0	40·5	40·0	41·0
Sun. ..	13	0	39·5	38·5	35·5	36·0	37·5	43·0	48·0	47·0	44·0	41·0	39·5	39·0	41·0
Mon. ...	14	0	39·5	38·5	36·5	36·0	37·0	41·5	44·0	44·5	42·5	40·5	40·0	40·0	40·0
Tues. ...	15	0	40·0	40·5	38·0	35·5	36·0	41·0	45·5	46·5	42·5	40·0	40·5	40·5	40·5
Wed. ...	16	0	40·5	39·0	37·0	35·0	36·5	43·5	48·5	47·5	44·0	42·0	41·5	40·0	41·0
Thur. ...	17	1	39·5	38·5	38·5	38·0	36·0	41·0	48·0	51·0	50·5	44·0	39·5	38·0	42·0
Fri. ...	18	1	40·5	41·0	36·0	34·5	35·5	41·0	47·0	47·0	42·5	40·0	40·5	40·0	40·5
Sat. ...	19	0	37·5	37·0	36·0	35·5	36·0	39·0	44·0	45·5	43·0	40·5	38·5	34·5	39·0
Sun. ...	20	0	34·5	36·0	35·5	34·5	37·0	41·0	45·5	47·5	45·5	42·5	40·0	39·0	40·0
Mon. ...	21	0	37·5	37·0	35·0	35·0	37·0	39·5	43·0	43·5	42·0	41·0	39·5	37·5	39·0
Tues. ...	22	1	37·0	38·5	36·0	32·5	35·0	42·0	47·5	48·0	47·0	45·5	41·5	41·0	41·0
Wed. ..	23	1	37·0	38·5	42·5	37·0	39·0	44·5	49·5	47·5	42·5	40·5	40·0	38·0	41·5
Thur. ..	24	0	38·0	38·5	34·0	33·5	36·5	42·0	46·0	45·0	43·0	40·5	40·0	39·5	39·5
Fri. ...	25	0	40·0	40·5	37·0	36·0	36·5	39·5	45·0	45·5	41·5	40·0	40·0	40·5	40·0
Sat. ...	26	0	40·5	39·0	36·0	34·0	36·0	44·0	50·0	47·0	40·0	39·0	40·0	40·0	40·5
Sun. ..	27	0	40·0	39·0	37·0	37·5	40·0	46·0	49·5	48·5	43·0	41·0	40·5	40·5	42·0
Mon. ...	28	0	39·5	38·5	36·5	34·0	36·5	43·0	48·0	47·5	43·0	40·5	40·5	40·5	40·5
Tues. ..	29	0	40·5	38·5	35·5	34·0	36·5	43·5	47·5	46·5	44·5	42·0	41·5	40·5	41·0
Wed. ...	30	0	37·0	37·5	36·0	35·5	37·5	42·0	46·0	46·5	44·0	42·0	41·0	40·5	40·5
Thur. ...	31	0	39·0	39·0	37·0	36·5	37·0	43·5	—	—	—	40·5	39·5	40·0	—*
	August														
Fri. ..	1	1	40·0	40·5	37·5	36·5	37·5	40·5	45·0	46·0	41·5	41·5	42·5	40·5	41·0
Sat. ...	2	1	36·0	35·5	36·5	36·5	36·5	39·5	44·5	46·5	45·0	42·0	39·0	39·0	39·5

Diurnal Inequality (i.e., departure from mean value for day).

	1h.	2h.	3h.	4h.	5h.	6h	7h.	8h.	9h.	10h.	11h.	12h.
July, 1918	-1′·1	-1′·3	-2′·0	-2′·7	-3′·9	-5′·2	-5′·2	-4′·7	-3′·4	-1′·1	+2′·1	+4′·9
June, 1919	-1·9	-2·1	-2·0	-2·9	-4·4	-5·8	-6·4	-5·8	-4·0	-1·2	+2·2	+5·3
June, 1918	-0·8	-1·0	-1·6	-2·8	-4·0	-4·9	-5·2	-5·1	-3·9	-1·3	+2·5	+4·9

	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
July, 1918	+6′·3	+6′·5	+5′·6	+4′·2	+2′·5	+1′·2	+0′·1	-0′·4	-0′·3	-0′·5	-0′·7	-0′·9
June, 1919	+7·1	+7·5	+6·5	+5·0	+3·3	+1·7	+0·7	+0·3	-0·1	-0·5	-1·0	-1·5
June, 1918	+6·4	+6·4	+5·3	+3·5	+1·7	+0·7	0·0	-0·1	+0·1	+0·1	-0·4	-0·8

Mean Value for Month.

July, 1918.	June, 1919.	June, 1918.
14° 50′·4.	14° 41′·0.	14° 51′·2.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G.M.T.

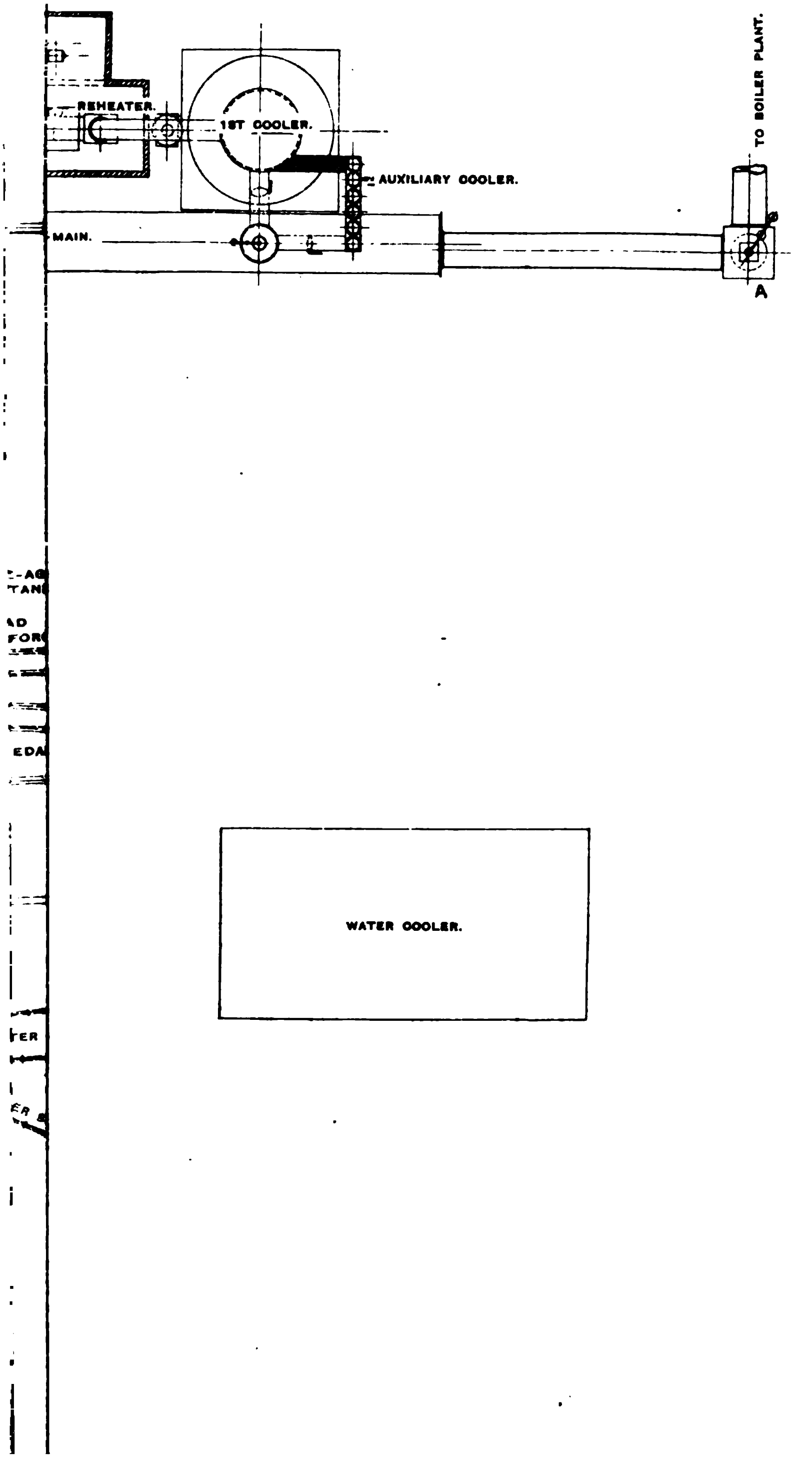
Character "0" means a day wholly free from any but small disturbances.

„ "1" „ „ part or all of which is moderately or considerably disturbed.

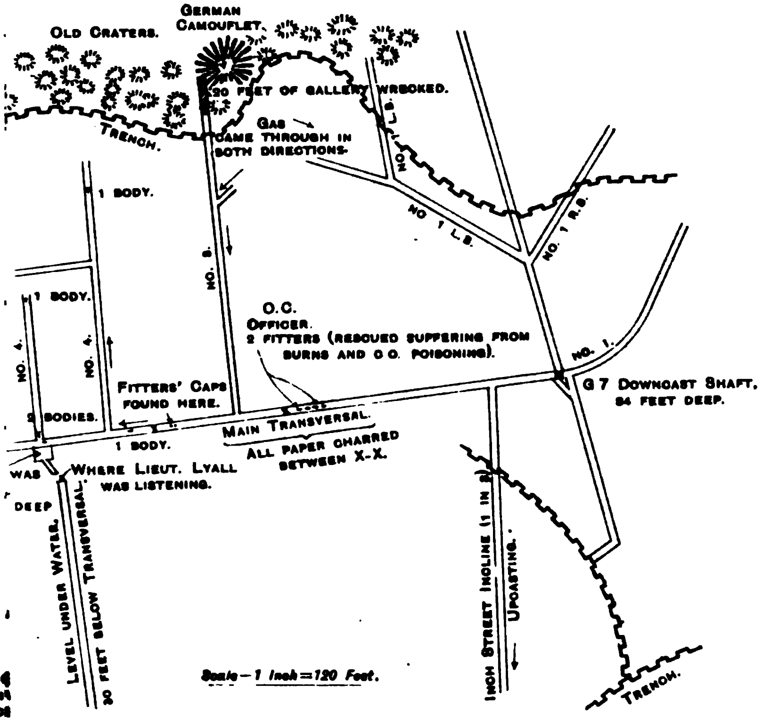
„ "2" „ „ part or all of which is highly disturbed.

* Owing to loss of trace between 12h. and 18h., some data are lacking for July 31st.

OUT OF NO. 2 POWER PLANT.

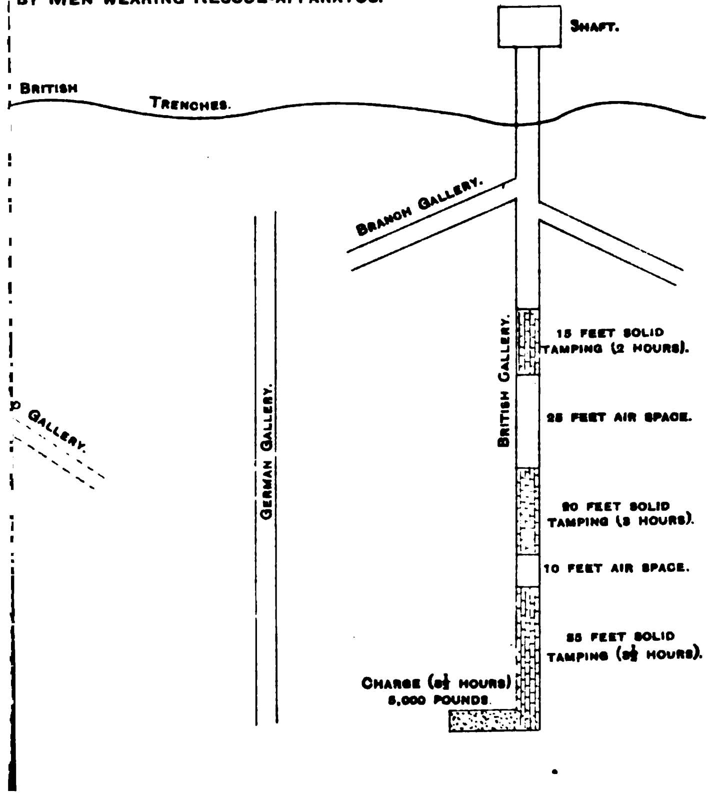

REHEATER.
1ST COOLER.
AUXILIARY COOLER.
MAIN.
TO BOILER PLANT.
A
WATER COOLER.

USTRATING AN EXPLOSION OF GAS FROM A GERMAN CAMOUFLET.


German Camouflet.
Old Craters.
120 feet of gallery wrecked.
Gas came through in both directions.
Trench.
No. 1 L.S.
No. 1 R.S.
1 body.
No. 8.
1 body.
No. 4.
No. 4.
O.C.
Officer.
2 fitters (rescued suffering from burns and C.O. poisoning).
No. 1.
G 7 Downcast Shaft, 84 feet deep.
Fitters' Caps found here.
2 bodies.
Main Transversal.
1 body.
All paper charred between X-X.
was
Where Lieut. Lyall was listening.
deep
Level under water.
20 feet below Transversal.
Inch Street Incline (1 in 8).
Upcasting.
Trench.
Scale—1 Inch = 120 Feet.

WHEN
DR
VIC
TU
GA
GIV

MINE GALLERIES, SHOWING AMOUNT OF CHARGE BY MEN WEARING RESCUE-APPARATUS.


Shaft.
British
Trenches.
Branch Gallery.
German Gallery.
British Gallery.
15 feet solid tamping (2 hours).
25 feet air space.
20 feet solid tamping (3 hours).
10 feet air space.
35 feet solid tamping (3½ hours).
Charge (3½ hours) 5,000 pounds.
D Gallery.

THE EXAMINATION OF COAL IN RELATION TO COAL-WASHING.

BY M. WYNTER BLYTH, B.A., B.Sc., F.I.C., AND L. T. O'SHEA, M.Sc., F.I.C.

Introduction.—There are two fundamental problems connected with coal-washing on which but little information is to be found, namely, what is to be retained as suitable material for coking, and how that is to be determined.

After searching the literature, the only reference we have found as to what should be retained in washed coal for coking purposes is in a paper communicated by Marsaut to the Société de l'Industrie Minerale in 1879,* of which the following extract is from a translation that appeared in *Engineering* in 1880:—

> "To form a correct idea of the efficiency of any coal-washing apparatus, it is not enough to look only at the percentage of ash in the washed coal, but the refuse must also be carefully examined as to the proportion of utilisable fuel carried away in it. The absolute amount of the refuse, depending merely on the impurity of the raw coal, is only of relative consequence; but its quality has a most important bearing upon the actual loss of fuel incurred in the washing.
>
> "On this point investigations have been carried on ever since 1864 by the simple mechanical expedient of testing all doubtful stuff in a bath of sulphate of zinc, the density of which is 1·4; taking this as the practical limit of density for coal as a utilisable fuel, all that floats on the liquid is coal to be saved, and all that sinks is refuse."†

The importance of examining the dirt going from the washer is fully recognized, but, as far as we can ascertain, there is no consensus of opinion as to what is to be considered coal and what dirt.

We have had the opportunity of examining certain contracts for coal-washeries in which the efficient working of the plant is to be determined by the percentage of dirt left in the washed coal and the percentage of coal in the dirt, without any condition as to what is to be considered coal and what dirt. This appears to us unsatisfactory. "What is coal" has been a fruitful subject for discussion and litigation, and it seems desirable that some system might be adopted which could be recognized as a standard whereby clean coal for coking purposes could be judged. Marsaut fixed a standard in 1879, but it appears that it is too rigid for general application, for the following reasons:—First, the standard by which the coal for coking purposes is to be judged is the purity of the coke it yields. Secondly, the purity of the coke from the consumers' point of view is judged by the ash and sulphur content. Thirdly, coal is a heterogeneous mixture of materials of different specific gravities which generally increase with the ash content; and the relative proportions of the constituents of different specific gravities and their ash contents will determine what proportion of any seam is suitable for retention in the washed coal.

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* "*Étude sur le Lavage de la Houille aux Mines de Bessèges,*" *Bulletin, Series* 2, 1879, vol. viii., page 387.

† *Engineering*, 1880-1881, vol. xxix., page 123.

Before defining what is to be considered coal, it is necessary to fix the standard of purity for the coke. Basing this on the ash and sulphur content, it is, as far as we are aware, assumed that the British practice is that the ash should not exceed 10 per cent. and the sulphur 1 per cent. in the coke; in Germany and in Belgium 9 per cent. of ash is taken as the maximum.

As regards the ash, it is easy to fix a standard of purity for the washed coal, when the percentage yield of coke is known, by fixing the limit of ash in the washed coal to that amount which will yield an ash content in the coke produced that shall not exceed 10 per cent. of the coke. The freedom from sulphur is a more complex problem. The sulphur in the coke does not depend only on the quantity of sulphur in the coal, but on the form in which it exists. Pyrites and gypsum, which contribute largely to the sulphur in unwashed coal, can easily be removed if not disseminated through the mass in fine particles, in which case the coal is probably unsuitable for coke-making; but after they have been removed, there is the organic sulphur, and the conditions which determine how much of this is retained by the coke are not fully understood, though the chemical character of the natural ash of the coal and the temperature and duration of distillation are said to influence that quantity. The reduction in the sulphur content of the coal by washing can be easily ascertained; but to fix a definite standard of purity with regard to it, by which to test the efficiency of a washer, is difficult, as the manner in which the sulphur exists in the coal in any one seam may vary in different parts of that seam.

We would suggest, therefore, that the purity of washed coal to be used for coking should be judged by its ash content as determined by incineration. The quantity of ash in the washed coal should be such that when the coal is converted into coke, the dry coke free from volatile matter will not contain more than 10 per cent. of mineral ash as determined by incineration.

If this basis were agreed upon, then any material in the seam which does not raise the ash in the coal beyond this amount can be included as coal for coking. This should not be difficult to determine so far as the washed coal is concerned, but any degree of purity as regards the washed coal can be obtained if no note is taken of what is coal in the dirt that comes from the washer. So that if the ash is recognized as a standard of purity in the washed coal, it must be coupled with some conditions as to the amount of coal in the dirt. What this is to be is a question depending on the character of the seam to be washed.

In considering the question of coal-washing from these points of view, it is evident that the problem can be solved only by a careful examination of each seam to be washed, and if a uniform method of testing the unwashed coal and the washed products be adopted.

As regards the examination of seams in order to ascertain their character for washing, all constructors of washeries make an exhaustive one, and doubtless have a large amount of information at their disposal regarding the coal-seams in the different British coalfields, which, if accessible, would be of the greatest value to the industry. What information is in the hands of different colliery firms we have no means of ascertaining, but we have been unable to find any reference in the literature to assist us in this matter. We have made an examination of certain seams in the Yorkshire and Derbyshire Coalfields, and although our investigation is far from being exhaustive, we record them in the present communication as a preliminary to further examination and in the hope that others interested in the problem may be encouraged to prosecute similar investigations and publish their results.

The method to be used for testing the quantities of coal in the dirt and dirt in the coal is of considerable importance and has claimed our attention. The test is one that depends on the method of sampling and the details of procedure.

In this investigation we have assumed that the ash in the washed coal is to be taken as the standard of purity by which to judge of its suitability for coke-making.

Every seam of coal consists of different bands usually separated by definite partings, and each band consists of a mixture of coal and dirt. By the term " dirt " we include any material which if left in the washed coal will raise its ash above the maximum laid down. The coal constituent in each band consists of materials of different specific gravities, and the specific gravity of the coal material rises with increase in the ash content. The constituents of any seam or of any band of coal or dirt can be separated, within certain limits, according to their specific gravities, by floating them in solutions of known specific gravity and determining the proportion that floats and the proportion that sinks. The ash in the floatings can be determined and the constituents separated into those suitable for coke-making and those not. It is, therefore, possible to determine for any particular seam or band of coal what amount can be used for coking purposes according to its specific gravity, as well as to fix the specific gravity of the solution in which to float the dirt for the purpose of determining the coal going away in the dirt. We have examined certain Yorkshire and Derbyshire seams, and our method is as follows:—

A complete section of the seam from roof to floor is taken. The importance of this is fairly obvious, as only by doing so can the true proportion of the different varieties to the whole seam be ascertained.

The size of the section is about 12 to 18 inches along the face and about 8 to 12 inches thick. The seam is then separated into its bands at the partings and each band sampled. The samples are made from the whole portion of the band by crushing it, so that the whole passes through a ½-inch square meshed sieve and is reduced by the method of quartering down to a small sample of about 1 kilogramme. From this a small sample of 200 grammes is taken. This is then floated in solutions of specific gravities, which usually are gradually increased by 0·05. A similar method has been adopted by Mr. W. McD. Mackey, who has floated coal in solutions differing in specific gravity by 0·1.*

Various solutions of metallic salts have been suggested, and are well known for the purpose of testing metallic ores. Maurice† gives a series of salts with the specific gravities of their solutions saturated at 15° to 20° Cent. These vary from calcium chloride (sp. gr., 1·411) to zinc bromide (sp. gr., 2·391). Mr. McD. Mackey‡ advocates a solution of potassium carbonate, which when saturated has the specific gravity of 1·53, and Prof. H. Louis§ recommends the use of zinc bromide, as it is possible to reach the specific gravity of 1·9.

We have found it convenient to use chloroform, which we believe was introduced some years ago by the Otto Coke Oven Company, as a medium in which to float coal. The specific gravity of pure chloroform is 1·526 at 0/4°, 1·5009 at 15/15°, and 1·4849 at 25/25° Cent. The chloroform used by us has a specific gravity of 1·48 to 1·49 at 15° Cent., and the specific gravity of the floating solution can be easily adjusted to any figure by the addition of methylated spirits or ethyl alcohol, with which chloroform is miscible in all proportions. As the specific gravity of chloroform varies considerably with the temperature, it is important therefore to work at a uniform temperature or carefully test and adjust the specific gravity of the solution before using it. An ordinary hydrometer is sufficiently accurate for this purpose.

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* *Journ. Soc. Chem. Ind.*, 1904, vol. xxiii., page 431.

† *Comptes Rendus Mensuels des Réunions de la Société de l'Industrie Minerale.* 1899, pages 144-165.

‡ *Loc. cit.*

§ *Journ. Soc. Chem. Ind.*, 1911, vol. xxx., page 662.

Chloroform offers many advantages over salt solutions. It readily wets the coal; it is very mobile; the floatings or sinkings do not require washing, but after filtration can be dried forthwith, and the drying is complete in about an hour. It is necessary to dry for an hour when mixtures of chloroform and methylated spirits are used, to ensure the complete evaporation of the latter. Calcium chloride, zinc chloride, and zinc bromide solutions of high specific gravity are very viscous; they do not readily wet the coal, and the amount of floating unmoistened dust may be considerable unless great care is taken in moistening the coal in the first instance. The solutions can be removed from the floatings or sinkings only by washing with hot water, and this, together with the increased time required to dry the sample before weighing, increases considerably the time required to carry out the process.

The specific gravity of the coal is taken by selecting pieces from the sample, carefully removing all dust by brushing, and using an ordinary specific-gravity bottle with methylated spirits. We have found it convenient, in order to avoid inclusion of air-bubbles, to moisten each piece of coal with methylated spirits, to have the specific-gravity bottle completely full of spirit, and to insert carefully each moistened piece into the bottle, only releasing it when completely submerged. We have also taken the specific gravity in chloroform, but the volatility of this liquid is an objection, as is also the fact that it is specifically heavier than coal. We have sometimes taken the specific gravity of large lumps of coal in water in the following manner:—A wide-mouthed specific-gravity bottle, similar to that used for taking the specific gravity of tar, serves the purpose. A carefully-selected lump of coal is well moistened with methylated spirits and slowly inserted into the bottle, previously filled with water; when it is completely immersed in the water, the lump is released. The water is then changed two or three times in order to remove any methylated spirit, and the specific gravity determined in the usual way. The moistening with methylated spirits ensures the complete wetting of the coal with water, and, if carefully inserted, no air-bubbles are carried down by the coal. We have also used the Westphal balance.

The specific gravity of the seam examined varies within narrow limits, and is generally less than 1·3, even in those cases where it has been determined in the lump. The samples are then subjected to a fractional separation by floating in solutions of the different specific gravities. The following two methods have been adopted—

(1) The 200 grammes of coal are treated in a suitable vessel

with about 500 cubic centimetres of solution of known specific gravity, well stirred, and allowed to stand for twenty minutes. The floatings are then skimmed off or removed by causing them to overflow by slowly adding more of the solution at a point midway between the floatings and the sinkings. A special apparatus was designed for the process, consisting of a cylindrical vessel fitted at the top with a sloping lip forming a shoot, over which the excess can flow into a funnel placed to receive it. The addition of the solution was effected down a tube which joined the cylindrical vessel at a point about midway between the top and the bottom.

Starting with the solution of lowest specific gravity, the floatings were collected and weighed, whilst the sinkings after the removal of the floating liquid were treated with the solution of next higher specific gravity, and so on, until the sample was separated into several fractions; finally, the sinkings in the solution of the highest specific gravity were weighed.

(2) In the second method a sample weighing somewhat more than 200 grammes is taken, well mixed, and quartered; and from each quarter 50 grammes are weighed. Each 50 grammes is separately fractionated in the following manner:—The sample is treated in a beaker with 100 to 250 cubic centimetres of the solution, well stirred, and allowed to stand for ten minutes. The floatings are then transferred to a separating funnel of special dimensions, designed by Mr. J. W. Lee, of the Hasland Coking Company, and described by him.*

The sinkings, as far as possible, are retained in the beaker; after well stirring, the contents of the funnel are allowed to stand for ten minutes, and about two-thirds of the solution with any sinkings are run off from the tap on to the sinkings in the beaker. The contents of the beaker are again well stirred and allowed to stand for five minutes, when the solution with any floatings are poured into the funnel. After well stirring and standing for another five minutes, the liquid is run off on to the sinkings in the beaker. If any appreciable quantities of floatings now form, the liquid is again transferred to the funnel; but if, as is generally the case, only a few pieces float, these are picked out and added to the contents of the funnel. These are then collected, dried, and weighed. The sinkings are then treated with the liquid of next higher specific gravity, as in the first method, and the process repeated, until finally the last sinkings are collected and weighed. After treating the four samples of 50 grammes each, the total weights are added together and the proportion of floatings calculated from the results so obtained. The minimum specific gravity for the floating liquid is not of material importance, provided that it is sufficiently low to float the cleanest fraction of the coal. We began at first with liquids of specific gravity of from 1·2 to 1·25, but subsequently adopted 1·3, as it was exceptional for any large quantity to float in liquid of 1·25 specific gravity.

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* *Joint Proceedings of English Junior Gas Associations*, 1914-1915, vol. v., pages 633 and 638.

TABLE I.—PROXIMATE ANALYSIS OF EACH BAND IN SECTIONS OF COAL FROM VARIOUS SEAMS.

Seam.	Band.	Moisture.	Volatile matter.	Ash.	Fixed carbon.	Sulphur.	Specific gravity.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
Fenton A	Roof coal	—	29·8	18·2	52·0	6·8	1·4
	Dirt	—	18·6	52·3	29·1	—	1·6
	Roof coal	—	35·1	6·6	58·3	3·02	1·3
	5 inches coal ...	—	28·5	8·4	63·1	2·39	1·32
	Dirt	—	15·6	60·5	23·9	0·48	1·79
	1 foot 2 inches coal	—	35·2	1·9	62·9	0·94	1·28
Fenton B	Roof coal	—	29·4	7·8	62·8	3·90	1·268
	4½ inches coal ...	—	32·1	4·0	63·9	1·86	1·294
	Dirt	—	9·5	83·1	7·4	0·38	2·06
	6 inches coal ...	—	31·0	2·7	66·3	1·73	1·274
	Dirt	—	16·9	61·3	21·8	0·67	1·758
	1 foot 6 inches coal	—	31·8	3·6	64·6	1·11	1·27
Whinmoor	Roof coal	—	26·9	4·1	69·0	1·18	1·333
	Dirt	—	15·8	43·4	—	1·64	1·583
	1 foot 4 inches coal	—	27·7	5·2	67·1	2·58	1·372
	Dirt	—	14·9	50·7	—	0·69	1·932
	8 inches coal ...	—	27·2	4·2	68·6	2·12	1·359
Barnsley ...	Bags	1·78	34·84	2·18	61·2	1·03	1·28
	Top softs	2·54	38·65	7·43	51·56	2·06	1·28
	Hards	2·42	37·07	4·98	55·38	0·75	1·27
	Black list	1·96	30·14	11·74	56·16	0·48	1·31
	Hards	2·49	33·11	2·4	62·00	0·58	1·27
	Softs	1·71	33·51	2·31	62·47	0·81	1·27
Parkgate ...	Top softs	—	28·5	4·1	67·4	2·457	1·32
	Clod	—	—	88·95	—	—	2·00
	Roof coal	—	25·1	12·6	62·3	5·53	1·5
	Top coal	—	26·0	7·3	66·7	4·283	1·31
	House coal	—	26·1	8·0	65·9	2·201	1·29
	Hards	—	29·6	2·8	67·6	0·76	1·28
	Branch	—	28·5	3·6	67·9	0·56	1·27
	Dirt	—	18·7	30·0	57·3	0·41	2·13
	Bottom softs ...	—	29·6	6·9	63·5	1·79	1·29
	Inferior coal... ...	—	23·7	23·9	52·4	2·27	1·68
Deep Softs	Top coal	3·15	35·86	6·50	34·50	2·35	1·26
	Top brights	3·98	34·32	2·35	59·18	0·95	1·28
	Hard band	2·80	36·87	1·8	58·53	0·86	1·25
	Bright coal	4·26	32·64	1·35	61·75	1·13	1·27
	Soft coal	—	—	—	—	—	1·26
	Bottom coal ...	2·62	34·38	6·15	56·85	3·78	1·29
Tupton ...	Roof coal	2·73	32·05	8·99	56·23	3·85	1·328
	No. 1	3·06	34·44	7·39	55·11	2·99	1·318
	No. 2	3·49	34·16	3·27	59·08	2·38	1·284
	No. 3	2·78	35·00	2·04	60·18	2·02	1·275
	No. 4	3·74	32·16	1·99	62·11	1·221	1·268
	No. 5	2·99	34·23	5·02	57·76	1·099	1·278

The following seams have been tested:—The Fenton, Whinmoor, Barnsley, and Parkgate from Yorkshire collieries, and the Deep Softs and Tupton from Derbyshire collieries. The sections of the seams are as follows:—

(1) *Fenton Seam A*: Roof coal, 4 inches; dirt, ¾ inch; roof coal, 3½ inches; coal, 5 inches; dirt, 2 inches; coal, 1 foot 2 inches.

(2) *Fenton Seam B*: Roof coal, 4½ inches; coal, 4½ inches; dirt, 3 inches; coal, 6 inches; dirt, 1¼ inches; coal, 1 foot 6 inches.

(3) *Whinmoor Seam*: Roof coal, 7 inches; dirt, 1 inch; coal, 1 foot 4 inches; dirt, ½ inch; coal, 8 inches.

TABLE II.—RESULTS OF SEPARATIONS.

Seam.	Band.	Fractions floating in						Sinkings, in
		1·25	1·3	1·35	1·4	1·45	1·48	1·48
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent	Per cent	Per cent.
Fenton A	Roof coal	—	30	—	40	18	—	12
	Dirt	—	Trace	—	Small	—	—	99
	Roof coal ...	—	88	—	Small	6	—	3
	5 inches coal ...	—	75·4	—	Small	17	—	4·8
	Dirt	—	Trace	—	Small	—	—	99
	1 foot 2 inches coal	—	98	—	Small	—	—	Nil.
Fenton B	Roof coal ...	—	47·2	47·2	2·0	4·0	—	0·6
	4½ inches coal ...	—	82·4	14·4	0·6	2·6	—	2·0
	6 inches coal ...	0·4	92·4	6·0	0·2	—	—	1·2
	1 foot 6 inches coal	—	88·0	5·8	1·0	1·6	—	3·6
Whinmoor	Roof coal ...	11·2	68·8	14·8	0·4	2·8	—	0·2
	1 foot 4 inches coal	12·0	73·2	2·0	1·6	7·5	—	4·6
	8 inches coal ...	0·4	93·2	0·4	1·4	0·5	—	1·6
Barnsley	Bags	—	97	1·5	0·8	—	0·3	0·4
	Top softs	—	48·28	20·27	8·43	—	6·57	12·15
	Hards	—	52·36	16·24	19·49	—	9·17	1·26
	Black list ...	—	72·5	2·5	1·5	—	7·5	16·0
	Hards	—	84·75	13·5	1·5	—	0·25	Nil
	Softs	—	97·7	1·0	0·5	—	0·5	0·3
Parkgate	Top Softs ...	74				7·80		18·2
	Clod	—				—		100·0
	Roof coal ...	64				9·0		27·0
	Top coal	85				0·4		14·6
	House coal ...	92·5				5·0		1·5
	Hards	96				1·3		2·7
	Branch	99·4				0·3		0·2
	Dirt	—				—		100·0
	Bottom softs ...	98·4				1·0		0·6
	Inferior coal ...	21·8				2·7		75·5
Deep Softs	Top coal	2·38	78·69	8·25	1·99	—	0·25	6·48
	Top brights ...	—	82·92	11·92	1·09	—	0·77	2·72
	Hard band ...	—	70·29	23·29	3·72	—	0·81	1·00
	Bright coal ...	—	89·18	6·39	1·53	—	0·78	0·82
	Soft coal	—	57·97	27·77	7·42	—	3·47	8·20
	Bottom coal ...	—	57·49	21·45	5·57	—	5·73	8·39
Tupton	Roof coal ...	—	59·66	19·22	6·85	—	3·78	8·18
	No. 1	—	74·19	10·77	1·72	—	1·88	8·05
	No. 2	—	76·39	14·95	3·75	—	0·66	1·18
	No. 3	—	82·39	12·52	1·14	—	0·40	0·96
	No. 4	—	88·37	5·04	2·17	—	1·07	1·28
	No. 5	—	68·82	15·61	5·25	—	3·07	3·97

(4) *Barnsley Seam*: Bags, 1 to 3½ inches; top softs, 1 to 7½ inches; hards, 7½ inches; black list, 3½ inches; hards, 1 foot 1 inch; softs, 2 feet 2½ inches.

(5) *Parkgate Seam*: Top softs, 8 inches; clod, 9 inches; roof coal, 3½ inches; top coal, 3¾ inches; house coal, 11½ inches; hards, 9 inches; branch, 1 foot; dirt, 2 inches; bottom softs, 1 foot 3 inches; inferior coal, 2 inches.

(6) *Deep Softs*: Top coal, 1 foot 1 inch; clod, 1 foot; top brights, 8 inches; hard band, 4 inches; bright coal, 7½ inches; soft coal, 7½ inches; bottom coal, 2 feet; spoil coal, 1 inch.

(7) *Tupton Seam*: Roof coal, 1 foot 4 inches; dirt band, 1¾ inches; coal, 4 feet 1¾ inches. The 4 feet 1¾ inches of coal is alone used for coking, and appears to be made up of different varieties. There are a number of bands of fusain (mother-of-coal), which appear to form natural partings. By means of these bands the section was separated into five parts numbered from the top downwards—No. 1, 11 inches; No. 2, 7 inches; No. 3, 7¾ inches; No. 4, 1 foot 6 inches; and No. 5, ½ inch. The proximate analysis of each band in the section is given in Table I.

There is nothing to be concluded from these analyses but what is already well known. Generally, the specific gravity increases with the ash content, but, as is evident, no definite relation can be established between ash content and specific gravity, as if the increase is due to admixed mineral matter, the resultant specific gravity will depend on the relative specific gravities of the coal substance and mineral matter and on the proportions in which they are mixed. One point may be specially noted, namely, that the analysis of the same seam varies in different parts. The two sections of the Fenton Seam were taken from neighbouring collieries about 2 miles apart, and the analyses of the different bands show considerable differences, especially in respect of the ash and specific gravity.

TABLE III.—DETERMINATION OF THE ASH IN EACH FRACTION.

Seam.	Band.	Percentage of ash in fraction floating in						Ash in sinkings in 1·48
		1·25	1·3	1·35	1·4	1·48		
Deep Softs	Top coal ...	1·07	1·17	3·41	6·30	Too small to estimate.	—	45·10
	Top brights ...	—	0·91	3·08	3·51	14·92	—	49·41
	Hard band ...	—	0·69	1·92	4·06	9·21	—	33·46
	Bright coal ...	—	1·17	3·67	3·23	13·50	—	44·84
	Soft coal ...	—	2·33	5·98	9·60	14·55	—	49·96
	Bottom coal ...	—	1·88	4·17	7·05	11·75	—	—
Tupton	Roof coal ...	—	1·88	5·15	8·40	13·5	—	46·99
	No. 1	—	1·75	4·60	10·16	15·67	—	64·00
	No. 2	—	1·59	3·84	5·24	8·75	—	49·97
	No. 3	—	1·42	3·19	5·32	7·14	—	51·50
	No. 4	—	1·00	3·26	4·68	8·41	—	42·00
	No. 5	—	1·76	4·65	8·66	14·28	—	40·52

The results of the separations into fractions are given in Table II. In the case of the Fenton, Whinmoor, Barnsley, and Parkgate Seams the first method of separation was used, and in that of the Deep Softs and Tupton the second method.

Determinations of the ash in each fraction were made in the case of the Deep Softs and Tupton Seams. The results are given in Table III.

A comparison of these results shows (1) that between 85 and 95 per cent. of the coal substance floats in liquids of 1·35 specific gravity, and in liquids of between 1·4 and 1·48 specific gravity comparatively small quantities float; and (2) that, as far as the seams examined are concerned, all the material sinking in liquids of 1·48 specific gravity is not coal for coking purposes.

From the estimation of the ashes in the Deep Softs and Tupton Seams, fractions floating in liquids of 1·3 and 1·35 specific gravities may be used for coke-making as far as the ash is concerned. The high ash in the fractions floating in liquids of 1·4 and 1·48 specific gravities may give rise to doubt. Calculations from the results obtained and the proportion which each band bears to the total coal in the seam will give some indication of the ash likely to result if these are included, and a determination of the ash in all material floating in liquids of 1·48 specific gravity will decide whether these fractions should be included.

In the case of the Deep Softs a calculation shows that if all the material floating in solutions up to 1·48 specific gravity is included, the ash of the floatings will be about 2·29 per cent.

For the purposes of coking, therefore, in the seams concerned 1·48 specific gravity may be taken as the specific gravity which separates coking material from dirt.

Other deductions are possible from these results.

A comparison between the specific gravity of the clean coal and that of the dirt will give indications of the amount of sizing necessary for the best washing in the case of washers where the coal is sized before washing. The specific gravity of the dirt in the seams examined varies from 1·6 to 2·46, and that of the clean coal from 1·27 to 1·4. By taking the maximum specific gravity of the coal in any seam and the minimum specific gravity of the dirt in the same seam, the relative sizes of particles of dirt and coal that can be separated can be calculated. In the case of the Fenton Seam A, if the roof coal is included the relative sizes of particles of coal and dirt that can be separated are as 1·5 to 1, whereas if the roof coal be excluded the relation between the sizes is 2 to 1; and in the case of the Fenton Seam B, if the roof coal is included the relation between the cases is 2·6 to 1, and if excluded, 2·4 to 1. In the case of Fenton Seam A, it will be easier to wash the coal if the roof coal is excluded, but in the case of Fenton B, it will make practically no difference.

The Whinmoor Seam should be a difficult seam to wash, as the relative sizes of particles that can be separated are as 1·6 to 1. Considerations such as this may lead to decisions as to whether any portion of a seam should be excluded; these may be based on its purity, or specific gravity, or on both, and in this respect the Fenton A affords an example; not only does it seem desirable to exclude the roof coal on account of its specific gravity, but its analysis shows it is also desirable on the ground of impurities.

The results we publish can only be considered preliminary to further investigation. It is possible to foreshadow other conclusions that may be drawn from them—for instance, the proportion in which the coal from various seams in any colliery should be mixed in the coking slack to give the best results.

In making our investigation of the coal-seams we were most struck with the irregularity of the results obtained. We found that three individuals working on carefully-mixed and quartered samples obtained widely different results, and even one individual working on samples of the same coal may obtain results which differ considerably.

Table IV.—Results of Fractional Separation of the Tupton Seam, each sample weighing 50 Grammes.

	Fractions floating in				Sinkings in 1·48.		Fractions floating in				Sinkings in 1·48.
	1·3 per cent.	1·35 per cent.	1·4 per cent.	1·48 per cent.			1·3 per cent.	1·35 per cent.	1·4 per cent.	1·48 per cent.	
Roof coal	60·42	20·80	6·84	3·10	6·48	No. 3 ...	86·94	9·90	0·84	0·16	0·22
	61·86	16·82	8·18	3·28	7·56		81·78	13·70	1·14	0·42	0·44
	57·94	20·72	4·88	4·64	9·72		81·68	11·84	1·06	0·32	1·94
	58·42	18·56	7·50	4·12	8·90		79·16	14·62	1·52	0·70	1·34
Average ...	59·66	19·22	6·85	3·78	8·16	Average ...	82·39	12·52	1·14	0·40	0·98
No. 1 ...	70·96	15·88	1·72	3·26	5·15	No. 4 ...	90·48	4·20	1·44	0·74	1·24
	74·36	9·52	1·52	2·36	8·82		86·46	5·44	2·36	1·54	1·32
	75·06	8·90	2·18	1·06	9·30		88·58	4·74	2·72	0·90	0·98
	76·38	8·80	1·48	0·84	8·94		87·98	5·68	2·18	1·10	0·76
Average ...	74·19	10·77	1·72	1·88	8·05	Average ...	88·39	5·01	2·17	1·07	1·07
No. 2 ...	74·60	18·36	2·46	0·62	1·26	No. 5 ...	67·53	14·93	5·10	4·70	4·30
	77·06	13·38	4·70	0·66	1·10		66·87	15·88	6·20	3·53	4·10
	75·64	14·90	3·50	0·72	1·34		71·02	15·98	4·47	2·07	3·18
	78·28	13·16	3·64	0·66	1·04		69·89	15·66	5·25	2·00	4·30
Average ...	76·39	14·95	3·57	0·66	1·18	Average ...	68·57	15·61	5·25	3·07	3·97

The results given in Table IV. are an example of what we have found generally. The samples were treated by the second method previously described, and the percentages of floatings obtained from each 50 grammes were calculated.

These irregularities appear to us to be due to a variety of causes incident on the difficulty of obtaining a true sample. First, the material consists of particles of different sizes, and the proportion of dirt particles above a certain specific gravity to coal particles below the same specific gravity is not the same for each definite size of particles; in fact, the proportion of dirt particles to coal particles generally increases as the size diminishes. Secondly, in sampling a mass of coal by the method of quartering, there is a tendency for the mass to segregate according to the size of the particles, the largest particles rising to the top of the sample and the smallest sinking to the bottom; so that however carefully a sample is made, it is difficult to obtain a proper proportion of each size in the whole sample taken. Thirdly, in order to obtain a true result it is necessary that the relation between the dirt particles to coal particles in each of the sizes that compose the sample shall represent the average in each case, and this is rendered exceptionally difficult, because in estimating dirt in coal the dirt particles are distributed through the mass at necessarily considerable intervals, and in estimating coal in dirt the same remark applies to the coal particles. Now if we take a comparatively simple case in which all the particles of coal and dirt are of the same size, the problem may be compared with the case of a number of balls, consisting of an unknown number of black balls (dirt) and white balls (coal), from which a number are to be drawn in order to determine the relative number of black and of white present. In order to get a fair average, it will be necessary to make either a large number of separate trials or to draw a large number of balls—that is, particles—at one time. If this is true, the larger the particles the greater the weight of sample that must be taken, so that in the case of an actual sample of coal or dirt for testing the weight taken must be determined by the proportion of the largest particles present, assuming that in any sample the number of the largest sized particles is smaller than that of any of the smaller sizes.

The actual number of particles to be taken will depend on the degree of mean probable error with which it is decided to be satisfied. We think that ±0·5 per cent. is quite sufficient, and to obtain this result we believe about 2,000 particles must be taken. We have arrived at this figure as follows:—

We took 270 counters in a box, of which 13·33 per cent. were coloured green, and drew ten; the green counters drawn were counted, the counters replaced and another ten drawn; this was repeated ten times till 100 had been drawn. This operation was then repeated until 1,000 had been drawn and the probable mean error calculated. The result obtained was ±0·57.

This method is hardly analogous to taking a sample of coal; consequently we took a number of counters at random from a bag containing 10 per cent. of white, and determined the percentage of white counters drawn. The counters so drawn were returned to the bag and a second lot drawn. The operation was repeated ten times. In the ten drawings a total of 974 counters were drawn, and the probable mean error calculated from the result was 0·66 per cent.; a second ten drawings were made, in which a total of 1,030 counters were drawn, and the calculated mean probable error was ±0·74. The probable mean error was then worked out for the whole 2,004 counters drawn, and the result was 0·47. We are aware that a sample of coal is more complex than a mixture of counters all of the same size, but the results suggested to us that if the sample of coal to be tested were first sized, and each size tested separately, the number of particles in each separate test should be about 2,000.

A large sample of unwashed coal was taken and sized; each size was separated in chloroform of 1·48 specific gravity, using small quantities at a time, until a definite weight in each case had been separated. The percentages of sinkings were separately determined and the mean probable error calculated; at the same time, the total number of particles treated was estimated. The results are recorded in Table V.

TABLE V.

Size of particles.	Over ½ inch.		½ to ¼ inch.		¼ to ⅛ inch.		⅛ to $\frac{1}{16}$ inch	
	Weight taken. grammes.	Percentage of sinkings in 1·48 specific gravity.	Weight taken. grammes.	Percentage of sinkings in 1·48 specific gravity.	Weight taken. grammes.	Percentage of sinkings in 1·48 specific gravity.	Weight taken. grammes.	Percentage of sinkings in 1·48 specific gravity.
	200	13·5	100	10·0	50	12·0	10	19·6
	200	4·5	100	7·5	50	13·0	10	17·4
	200	16·0	100	11·8	50	13·6	10	17·4
	200	6·0	100	8·5	50	15·0	10	18·8
	200	26·0	100	12·2	50	14·0	10	15·2
	200	8·5	100	15·0	50	14·0	10	17·6
	1000	15·0	100	13·5	—	—	—	—
	500	14·4	100	14·7	—	—	—	—
	—	—	100	8·5	—	—	—	—
	—	—	100	12·1	—	—	—	—
No. of particles ...	240		2,250		6,000		9,000	
Weight	2,700 grammes		1,000 grammes		300 grammes.		60 grammes.	
Probable mean error	± 1·90		± 0·55		± 0·28		± 0·41	

In the case of the over ½-inch sample, only 240 pieces were tested, and it is evident that this is too small a number, but the results with the ½ to ¼-inch samples and smaller sizes appear to bear out the conclusion that 2,000 particles will give a result within the standard we have laid down. With sizes over 1-inch about 30,000 grammes are required to give 2,000 particles. The size of the original sample is naturally governed by the size of the largest particle present, which means that the minimum weight of each size to be tested would be about as follows:—

Grammes.
Under $\frac{1}{16}$ inch = 10
$\frac{1}{16}$—⅛ ,, = 50
⅛—¼ ,, = 200
¼—½ ,, = 1,000
Over ½ ,, = 25,000, about 56 pounds.

As a general rule, mixed coking slack is passed over a ½-inch screen, so that ½ to 1-inch is separated, though not always, in samples of unwashed coal; often, however, the ½ to 1-inch is left in. The dirt coming from the washer is usually a mixture of that extracted from all sizes. This means that if the ½-inch stuff is taken out of the coking slack, the weight taken for the sample must contain at least 2 pounds of ½ to ¼-inch stuff, whereas if the ½ to 1-inch stuff is left in, the sample must be large enough to contain at least 56 pounds of these sizes. The last condition will generally control the size of dirt sample to be taken.

The difficulty of treating a large sample of 1 cwt. or more, consisting of all sizes, is very great, but if the sample is sized before testing, the process is much simplified. Our procedure is as follows:—

(*a*) *Unwashed Coal.*—Samples are taken by collecting the complete contents of a bucket on the elevator at regular intervals during the day till a sample of about 5 cwt. is obtained; this by quartering is reduced to about 1 cwt. The sample is then passed through different sized meshes—1, ½, ¼, ⅛, 1/16 inch—each quantity being weighed. Enough of each size is then taken to ensure at least 2,000 particles being present in each sample, and this is tested separately by the float-and-sink test. From the individual results obtained the percentage of sinking on the whole sample is calculated. The large material, bulky as it is, presents little difficulty. Owing to its size it can be dropped very rapidly into the solution one or a dozen pieces at a time, and the floating particles removed as the test proceeds. In fact, we find it is quite possible to use chloroform without entailing an excessive loss. The ½ to ¼-inch material can be treated in the same way, as, owing to the removal of the dust, the separation is rapid and sharply defined. The funnel can easily be used for the ⅛ to 1/16-inch and the 1/16-inch and under material.

(*b*) *Washed Coal.*—As we have already pointed out, the quality of the washed coal is best judged by its ash content, and for routine control we believe it is a better test than a float-and-sink test. Still, there are circumstances when it is advisable to make float-and-sink tests on the washed coal, as, for instance, in testing a washer which has been erected under a guarantee as to the sinkings and floatings. It also appears profitable to make periodical tests in the ordinary course of working. In this case the sample is made by taking the complete contents of one of the elevator-buckets at intervals of half-an-hour during the day. The sample is then treated as in the case of the unwashed coal, dried, separated into sizes, and tested.

(*c*) *The Dirt.*—The ash content of the dirt cannot be used to estimate the coal carried away, and float-and-sink tests are necessary daily. Samples are taken from the dirt-elevators in a similar manner to that of the coal samples, or by filling at definite intervals a 2-gallon bucket with the dirt as it is discharged from the washer. The whole sample so obtained is treated in the same manner as the sample of unwashed coal.

As an illustration, we give the actual procedure adopted to test the working of a washer erected under a guarantee as to sinkings and floatings, the washer being of the type that sizes after washing:—

(1) The individual wagons of unwashed coal were tested as to size of particles, dirt (sinkings in 1·48 specific gravity chloroform), and ash.

(2) The quantity of coal delivered to the washer was checked at intervals during the test.

(3) The washed small coal (coking slack) was sampled by taking the whole of the contents of one elevator-bucket per half hour; the whole sample was well mixed, spread on an iron plate, and quartered, from one quarter of which the sample for testing was taken by the method of quartering.

(4) The fine and large dirt samples were sampled in the same way as the washed coal.

(5) The washed nuts and beans were sampled from the wagons.

(6) Samples of the silt or slurry were tested.

(7) Samples of the crushed coking slack were also tested. The wet dirt, nuts, and beans were weighed, but as there was no provision for directly weighing the wet coking slack, its weight could only be estimated from the capacity of the storage bunkers, the number and average weight of the compressed cakes, the water in the slack, and the weight of dry coke made.

This example illustrates how many complications may arise, and renders it very difficult to ascertain with fair accuracy whether a guarantee based on the percentage of sinkings and floatings is being fulfilled. On the other hand, if the guarantee undertakes to leave only a certain percentage of ash in the washed coking slack, and a certain percentage of floatings in the dirt, the testing of the washer would be much simplified, and we believe would be fairer to both parties.

To what extent investigations on these lines are carried out by the managers in charge of washing plants we do not know. The washing expert who advises on the erection of washers must perforce carry out examinations of a similar character before he can advise or give any guarantee. It seems to us that it would be to the advantage of the coking industry and the efficiency of coal-washing if the results of such investigations were in the hands of the managers in charge of coking and washing plants. The results we publish can only be considered preliminary to further investigations; but if coal-washing is capable of scientific control, it can be achieved only by a more intimate knowledge of the material to be dealt with.

In conclusion, we would acknowledge the courtesy and assistance we have received at the hands of those colliery managers who have kindly supplied us with sections of the various coal-seams, and to express our thanks to Mr. M. Koyama, who has carried out a large number of the separations and analyses.

The PRESIDENT (Mr. G. Blake Walker): Could the authors suggest any practical method for the simplification of selection of samples with any reliable result? Doubtless each of the separate samples mentioned in the paper was subjected to a careful test, but I do not think that in the majority of cases such elaborate divisions can be made, and probably therefore similar results would not be obtained. Has a somewhat rougher means of reaching the desired end been suggested to the authors in the course of their experiments?

Mr. R. W. DRON (Glasgow): I am not quite sure as to the genesis of the paper, but I rather think that it was a lawsuit in which both Prof. O'Shea and I were engaged a few years ago. That lawsuit was due entirely to the fact that the buyer and the seller of a washer were content with a loose specification, with the result that Prof. O'Shea and I had to go into court and endeavour in the best way possible to explain what the requirements were.

The authors are now endeavouring to lay down some lines on which, on the erection of a washer, a clear definition can be made in the specification as to what the washer must do. They suggest 10 per cent. of ash in the coke as being a fair standard to take, but in the case of Scotland the bulk of our washers are not dealing with coking coal at all, but with ordinary commercial washed coal, so that a coking basis of that kind would hardly be applicable in the case of Scottish washers. In any case, the variation in the samples both of unwashed and washed coal makes this method somewhat uncertain when applied for the purposes of a specification.

In my opinion, the sink-and-float test is the proper one to apply to a washer at the time when it is taken over from the manufacturers. For that purpose a reasonable requirement would be that not more than 2 per cent. of the washed coal should sink in a solution of 1·48, and that not more than 1 per cent. of the refuse should float in a solution of 1·35. Between these limits one can arrive at a fairly good result in washing practice.

Float-and-sink tests as carried out by the authors would, I think, only be applicable to confirming the specification of the washer after it is erected. Colliery-owners cannot afford to employ professors to undertake these investigations every week. What is required on the erection of a washer is that it shall be tested thoroughly and found capable of doing the work it is intended to accomplish.

With regard to the ordinary working of the washer, the President's suggestion is one which the authors might follow up, in the way of devising simple float-and-sink tests for arriving at commercial results from week to week, so that the manager may know exactly what his washer is doing.

Mr. T. J. DRAKELEY (London): The chief question which needs deciding is whether, as the authors suggest, the purity of a washed coal is to be judged by its ash content. Naturally, one of the most important tests to determine whether any coal is suitable for a particular purpose such as coking is to estimate the ash content; but it does not necessarily follow that it is the best method of judging the quality of a washed coal. The ash test is not a satisfactory test of the quality of a washed coal, because it fails to differentiate between impurities which might have been separated from the coal and those impurities which form an integral part of the coal-particles themselves. During the process of washing, the materials are arranged in accordance with their specific gravities, and not necessarily in order of their ash contents. Thus, the average specific gravity of shale is about 2·40, and its ash content is often as high as 90 per cent.; on the other hand, iron pyrites has a specific gravity of 5·00, and on incineration in an open muffle-furnace leaves only about 67 per cent. of ash.

A float-and-sink test will indicate to what extent the washed product may be more perfectly cleaned by washing; indeed, the maximum purity of a washed coal is when all the particles float in the accepted high specific gravity solution, and this is the standard which should be kept in view. Then the ash content may be left to look after itself. An ash test alone fails to show what might be attained, and indicates merely the maximum amount of dirt which may be allowed in the washed product without seriously deteriorating the quality of the final coke.

A consideration of the question of the sulphur content makes the objection clearer and more pronounced. The authors state that the reduction of the percentage of sulphur by washing can be easily ascertained, but that to fix a definite standard of purity with regard to it, by which to test the efficiency of a washer, is difficult, as the manner in which the sulphur exists in the coal in any one seam may vary in different parts of that seam. The same assertion appears to be true of the ash; for the inherent ash content—that is, the inorganic matter which cannot be removed from the coal—varies throughout the seam.

Furthermore, as I have pointed out in my paper on "Coal-washing: A Scientific Study,"* the sulphur content is not necessarily reduced by washing, and a case is quoted (*loc. cit.*, page 440) where separation of a refuse containing little sulphur resulted in the percentage of sulphur in the washed coal exceeding that in the raw coal. The efficiency of that particular washer, however, was high when estimated by means of float-and-sink tests, but would be a negative amount if calculated on the sulphur estimations. Hence it seems to be an impossible suggestion that the efficiency may be judged from the sulphur content of the products.

The ash test also appears to be unfair, both to the purchaser and the guarantor of a washer, for the following reasons:—

(1) The purchaser may be content to pass as satisfactory a comparatively inferior coal because it satisfies the ash test; whereas by a float-and-sink test he may be led to make an attempt to obtain a more perfectly cleaned product.

(2) The guarantor can always claim, if any difficulty should arise, that the quality of the raw coal from the seam has changed. The authors mention in their paper this variation.

It may be noted that the authors state that the quality of the refuse is to be determined by the float-and-sink test. That means, of the refuse the material which floats should have been delivered with the washed coal. The obvious converse of this, since the refuse and washed coal are products of one operation, is to test the washed coal in the same solution and to state that of the washed coal the particles which sink should have been rejected by the washer as refuse. I have devised (*loc. cit.*, page 452) a method of calculating the efficiency of a washer from the results of float-and-sink tests, and this method has the special feature of allowing for variations in the quality of the raw coal. Incidentally, it may be of interest to observe that the ash contents of various washed coals from a washer bear a fairly definite relation to the corresponding sizes of the particles (*loc. cit.*, page 439). Raw coal of a diameter of 1¼ inches is most amenable to a reduction in ash content by washing. Hence a variation in the distribution among the various sizes that are washed may upset any calculations made on an ash-test basis.

With regard to the sample obtained from the coal-face, it would be interesting if the authors would state whether they found that sample at all comparable with an average mined sample. When I commenced the above-mentioned research on coal-washing, Mr. W. T. Molyneux (Wigan) and I sampled the seam of coal in a manner similar to that mentioned in the paper; but subsequently this process was abandoned for the following reasons:—

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* *Trans. Inst. M.E.*, 1917-1918, vol. liv., pages 418-459.

(1) The mined coal was always inferior to the face sample. The variation was over a wide range, and some mined coals yielded 50 per cent. more ash than the face samples, especially in the smaller sizes which pass to the washer.

(2) At most of the collieries coal from several seams was being washed in the same plant, and it was impossible to form any definite idea of the actual proportions in the washer at any moment selected for collecting the washed coal and refuse samples.

(3) Frequently the whole of the mined coal is not sent to the washer; it is screened, and only the small coal enters the washer.

The latter point involves the question of the distribution of the ash between the various sizes of the mined coal. A short time ago I commenced to investigate this question, but was unable to secure many results. One interesting result was given in the *Colliery Guardian* of January 31st, 1919, page 245.* The point is interesting and of importance, and possibly some member may be able to carry the matter further, so that a definite statement may be made concerning the distribution of the ash in the mined sample. It is of importance from the point of coal-washing.

From the preceding remarks it is seen that I consider that, as the object of washing is the removal of dirt-particles, the most reliable and scientific test of the quality of the washed product is a float-and-sink test, no matter to what use the coal is subsequently put.

Chloroform is certainly an excellent medium in which to carry out the float-and-sink tests. The cost is, however, very high; whereas calcium chloride may be obtained for about 2d. per pound, chloroform costs about 5s. per pound.

Mr. G. J. BINNS (Duffield): Can Mr. Drakeley give more details with regard to the form of the sulphur which was found in increased percentage in the coal? He has stated that there is an increased proportion of sulphur in the coal, and I would like to know what form the sulphur is in.

Mr. DRAKELEY: That is rather a difficult question to answer definitely, but I can say that the dirt-particles themselves contain very little sulphur. When these are removed, the concentration of the sulphur in the coal appears to increase. It is present largely as organic sulphur.

Mr. W. McD. MACKEY (Leeds): I think that we must take the paper as a contribution to the general question of coking. The authors have taken the ash sample as a basis on which to put the matter before us. I gather that they intend to make other contributions, and will probably go further. I have done much work on the same question, and I think that generally it bears out what the authors have put forward. With regard to the taking of the 10 per cent. of ash, I do not on theoretical grounds quite agree with that view. But, speaking as a man who has had a great deal of experience with blast-furnaces, I should imagine that a blast-furnace manager would forgive a great deal about the coke if the ash content was regular. The great trouble with the blast-furnace is that one gets a coke at one time with 5 per cent. of ash and at another with 15 per cent. Such a variation is bad for the furnace. Even the good coke is bad in that respect, because the burden of a furnace is regulated very largely according to the ash or the amount of carbon in the coke, which really means the ash. If one is making white iron and suddenly comes upon a coke with 15 per cent. of ash, and has been in the habit of using a coke with only 5 per cent., the furnace may go wrong; or, if one is making grey iron, one may get to a white iron without wanting it.

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* "Impurities in Raw Coal and their Removal," vol. cxvii.

Looking at the matter scientifically, I think something should be done with regard to the physical condition of the coke.

There have been two or three papers read before the Iron and Steel Institute on methods by which one can tell how the coke will act in the blast-furnace, some of which are quite good, I believe, and also in regard to the physical conditions of the coke. I remember one case in which a coal that was washed for a number of years gave an ash content of about 10 per cent. On putting up other washing plant, the ash content was brought down to 5 per cent., thus making a coke which was altogether unsuitable because it was too soft. I would like, therefore, to call the attention of the authors to the physical condition of the coke. I have more in mind blast-furnace coke, which has to stand conditions of being turned over under pressure and at a great heat. Various attempts have been made to test the coke in that connexion, and I think that the authors would do well, if, instead of taking the ash content only, they looked at the physical condition of the coke and considered that as well.

On one point I agree with the authors and with Mr. Drakeley, as I have found the same result. It is curious that in the coals which I have had to examine I have found the ash go down, but not the sulphur in anything like the same proportion. Looking at Table I., I see that comparatively little sulphur is got out in the dirt. I have not examined dirts for sulphur, but I have stated my own practical experience.

With reference to the use of chloroform, I share Mr. Drakeley's objection to it on account of the cost, although it may be very useful. Have the authors tried chloroform on very finely-ground coal? At one time I had to examine mine-dust. The first lot that came in could not be separated with potassium carbonate. Would it have been possible to separate it with chloroform?

Prof. O'SHEA (Sheffield): I think so. I have separated the coal when it has been completely ground, and there was no difficulty. The viscosity is such that the material is very readily separated; the operation, however, requires a little longer time.

Mr. MACKEY: I am glad to note that attention has been given to sampling. I agree in the main with what has been done, and I am pleased to note that attention is called to the desirability of putting sampling on a scientific basis, because careless sampling is one of the things from which chemists suffer very much. As a rule, sampling is fairly well understood in the coal-trade; so it is in the iron-trade; but I have known iron-ore not only carelessly sampled but carelessly handled after the sample was taken at the face. I might refer to the case of an ironstone mine which was almost closed because, although great care had been taken in the actual taking of the sections, when it came to the handling and the breaking-up of the sample, the best of the ore was knocked out and left on the floor and the bad was left in. I think it should be brought to the attention of everyone who takes samples that great care should be taken both in taking the samples and in handling them after they are taken.

Prof. HENRY LOUIS (Newcastle-upon-Tyne): The authors have gone into the question of sampling, and, as far as I can make out, they have worked upon determining the number of particles which they consider they ought to use in order to get a fair sample. Twenty years ago I did a good deal of work on the mathematics of sampling and on the application of the law of probabilities to sampling, and I do not agree that it is only the number of pulverized particles—that is to say, the fragments—which one ought to take into account. What should be taken into account is the number of coherent—I was going to say molecules—but I will say material particles of impurity.

I might illustrate the point in this way: If we are dealing with stuff through a ½-inch sieve, and we have all clean coal, except one piece of shale, the ½-inch lump of shale will get in somewhere; no matter how many million pieces are taken, we would never get a proper sample, quite obviously. If we have coal in which the mineral constituent is very finely disseminated, it is the size of the individual particles of that mineral constituent which has to be taken into account in determining the bulk of the final sample. That is the main point that one has to get at, and that is where I really find the greatest difficulty when trying to work out the problem from the point of view of the theory of probabilities.

The PRESIDENT: Do you exclude the larger particles?

Prof. HENRY LOUIS: No. In determining the size of the sample which has to be taken, we must take into account, not the size of the fragments with which we are dealing, but the size of the particles of dirt, or whatever it may be, in the sample that is being examined. If we are dealing with a coal in which the ash—the inorganic matter—is in particles of a thousandth of an inch in diameter, we can get an accurate sample by taking a much smaller quantity of coal than if we were dealing with a coal in which the inorganic particles are a tenth of an inch in diameter. That fact must be taken into account in determining the size of the sample which will give a result below any given probability of error.

I would like to direct the authors' attention to a paper detailing work done by a colleague of mine, Dr. Garrett, on the *x*-raying of coal, in which by taking *x*-ray skiographs of coal one can measure the actual size of the particles, although they are not visible in the coal.* By working in that way one can get exceedingly useful results for the object aimed at. In specifying washing results, I have always tried to stipulate that the percentage of ash in the coal and the percentage of organic matter in the refuse must not exceed so much. The exact figures will, of course, depend altogether upon the nature of the raw material with which one is dealing. The main point to which I want to draw attention is the advantage of using the *x*-ray method for examining one's coal and then determining the size of one's sample by reference to the dimensions of the actual particles of inorganic matter one wishes to separate out. My experience with regard to the sulphur quite coincides with that of the authors. When sulphur is present as iron pyrites, it is an easy matter to wash it out; but when, as I have proved to be the case, and as I believe is generally admitted, it is present as an organic sulphur compound, no amount of washing will have that effect.

Mr. A. E. FINDLEY (Sheffield) wrote: The tendency in modern coking practice appears to be to carbonize almost anything and everything that will cake, irrespective of the use to which the coke is to be put by an outside consumer. This state of things has been brought about by (1) the demand for benzol and toluol during the war; (2) a greatly increased demand for coke; and (3) the present need for fuel economy, which makes for little washing. It is noticeable that coal and iron companies usually pay more attention to washing before carbonization than do ordinary colliery companies. The following figures will give an idea of the extent to which coal is being washed in the Sheffield area:—

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* "The Use of *X*-Rays in the Examination of Coal," by F. C. Garrett and R. C. Burton, *Trans. Inst. M.E.*, 1911-1912, vol. xliii., page 295.

Dry coal	A.	B.	C.
	Per cent.	Per cent.	Per cent.
Ash	9·00	8·75	4·90
Ferric oxide (Fe_2O_3) ..	0·82	1·45	0·71

These coals were taken from the ram boxes at different collieries within the last month (May, 1919). It is obvious that the coke from A and B will not conform to the standard laid down by the authors, and will entail the use of large quantities of additional fluxing material and the formation of much additional slag in blast-furnaces.

The question of sulphur, which is also very important, but is not dealt with to any extent by the authors, often causes great anxiety to conscientious coke-oven managers. It is, for example, impossible to remove the sulphur from certain coals by washing. A slack from the Flockton Seam contained 3·16 per cent of sulphur and 14 per cent. of ash; it was separated in a 1·4 specific-gravity solution and 22·5 per cent. of dirt was removed. The clean coal then gave 1·87 per cent. of sulphur and 3·0 per cent. of ash. Another slack from the High Hazel Seam containing 1·69 per cent. of sulphur and 22·3 per cent. of ash was separated in the same way, and gave 25 per cent. of dirt, the clean coal containing 1·58 per cent. of sulphur and 3·0 per cent. of ash. Such coals would not be very suitable for coking unless they were mixed with coals from other seams which contained much less sulphur after washing.

When consumers decide to purchase coke only on calorific value and sulphur content, there will be a great improvement in the quality of bye-product coke. Managers will realize that it is to their advantage to see that the coal from certain seams does not go to the ovens, and they will have to take steps to prevent it from going there.

The following figures confirm those given in Table V.:—

	I.	II.	III.	IV.
	Per cent.	Per cent.	Per cent.	Per cent.
Dirt found ...	23·36	29·64	30·32	23·02

These figures were obtained on slack which had passed through a ½-inch mesh. Samples I. and II. were obtained on 50 grammes and III. and IV. on 100 grammes of the same slack.

Mr. SHERWOOD HUNTER (Manchester) wrote: I must congratulate the authors on the very fair way in which they have approached this difficult question. The checking of the work done by a coal-washery is comparatively easy if the subject is

SEPARATION FORM USED FOR SAMPLING COAL PRIOR TO INSTALLATION OF WASHER.

Slack below Mesh. *Results on Dry Coal.*

Size.	Per-centage of raw coal.	Ash in raw coal.	Sulphur in raw coal.	Floatings in 1·25 solution.	Ash in same.	Sulphur in same.	Floatings in 1·30 solution.	Ash in same.	Sulphur in same.	Floatings in 1·35 solution.	Ash in same.	Sulphur in same.	Floatings in 1·40 solution.	Ash in same.	Sulphur in same.	Floatings in 1·45 solution.	Ash in same.	Sulphur in same.	Floatings in 1·50 solution.	Ash in same.	Sulphur in same.	Sinkings in 1·50 solution	Ash in same.	Sulphur in same.	Loss.
¼ inch—1 mm.																									
1 mm.—¼ mm.																									
¼ mm.—0																									

NOTES.

Original Sample.

Ash ... ... %

Sulphur ... ... %

properly understood, as is so very well defined in the paper under discussion.

If it is understood that a coal-washery is laid down to separate useful material (coal) from useless material (dirt)—thereby making a really useful article out of a more or less useless article (unwashed coal)—the decision as to what is coal and what is dirt rests with the choice of a specific-gravity solution, the floatings in which are coal and the sinkings dirt. The greatest difficulty up to the present has been the fact that most washery contractors use the term "free coal" and "free dirt," which indicates a neutral zone between the coal and the dirt, and not a distinctive dividing-line. Generally speaking, "free coal" is assumed to be floatings in a 1·35 specific-gravity solution, and "free dirt" sinkings in a 1·5 solution, so that there is a substance between 1·35 and 1·5 which in the washed coal is coal and in the dirt, dirt. Seeing, however, that the margin allowed (generally 2 per cent.) is so small, this liberty of definition is not of very great importance. Nevertheless, it is doubtful and often disputed whether sinkings in 1·5 are really "free dirt" and the floatings in 1·35 "free coal." I agree with the authors that it would be preferable to fix upon a medium the floatings in which are "coal" and the sinkings "dirt," and regulate the guarantees accordingly. A medium could be established on the basis of ash in the coal, as suggested by the authors. It would be preferable to fix this medium to coincide with the yield of washed coal, and allow for a certain percentage of sinkings in the solution selected from the washed coal, and a certain percentage of floatings from the dirt washed out.

I am not in favour of giving guarantees for ash in the washed coal, but prefer the flotation test in a similar manner to that suggested for the dirt. The washery is a combination of machinery to separate heavy from lighter material, and only controls ash as it occurs in the material to be dealt with. In any case, it would be a simple matter, when the washery has been tested for conformity with the guarantees, for the owners of the plant to fix upon a certain maximum ash in the coal, and to check the washery from time to time on this basis, which method of testing is certainly quicker than the flotation test.

The suggested method for arriving at fair samples is excellent, as with the constant variation in the quality of coal spot samples are never reliable.

I attach a separation form, which my firm uses for sampling the coal prior to its installation in the washery. The whole of the plant is then laid out to deal with coal approximately of the constitution of the samples tested. Starting from the smallest sizes, we separate unwashed coal with which the plant is intended to deal into the following sizes:—

0 to ⅛ millimetre mesh.
⅛ ,, 1 ,, ,,
1 millimetre to ⅛ inch mesh.
⅛ inch to the size of fine coal (generally ⅜ inch).
Size of peas.
,, of nuts, etc.

These various sizes are then tested individually in their original condition, and, if necessary, for sulphur, as indicated on the form. Each size is then separately subjected to a flotation test in a 1·25 specific-gravity solution, the percentage of floatings being entered in the column under "Floatings, 1·25 solution." These floatings are tested, if necessary, for ash and sulphur. Sinkings in the 1·25 solution are then placed in a 1·30 solution, and so on, and continued until the sinkings of the final solution represent the dirt. If coal of a certain ash content is required, a theoretical yield can be quickly established from the proportions. In some cases, mostly with foreign coal, a secondary class of coal or "middles" has to be allowed for. This can be kept separate, or, if advantageous, broken up and re-washed. A certain margin is then allowed for estimating the actual yield and ash from the washery, which margin varies with the proportion of middles between the specific gravities of 1·4 and 1·55 found in the theoretical test.

Mr. E. NICHOLSON (Staveley) wrote: The paper should be of exceptional interest, both from the standpoint of the makers and that of the users of coke. One is surprised at the paucity of information published on the subject, and can only surmise that makers of various types of washers have a large stock of information " for private use only."

The first point in the paper that strikes me is the suggested 10-per-cent. ash standard for coke. As far as my experience with furnace cokes goes, this would certainly rule out a large number of Yorkshire and Derbyshire cokes that are supposed to be made from washed slacks. I can only surmise the reason, and apportion the blame equally between overloaded washers and their inefficient control, although the factor " what is dirt " doubtless enters into the argument.

A sliding scale for the selling price of cokes, with a 10-per-cent. ash standard, would probably tend to improve the quality. This method, I believe, has been found satisfactory in America.

I would like to have seen the two methods used by the authors in the separations compared, as method No. 2 appears to entail much more work than does the other, and unless the results obtained are superior it can hardly be worth while to employ it.

With regard to what I consider the most important point in the paper, namely, " The relative sizing necessary to get the best results on washing," I hope that in a future paper more data will be given on the subject, as I am at present unable to arrive at the authors' figures.

The suggestion to cut out a portion of any seam would be sure to meet with great opposition from mine managers, on the ground of impracticability; but this method would often have the effect of producing a good coking slack from a relatively poor one.

The final stages of the paper, dealing with the sampling and sizing necessary for purposes of checking the efficiency of a washer, go a long way towards proving that washeries should be scientifically controlled, whilst at the same time the authors have not made light of the difficulties of sampling, of dealing with large bulks of material, or of the precautions essential if the error is to be kept within well-defined limits.

The authors have laid down an excellent foundation for their promised further investigations, which I trust will have the effect of putting the manufacturers and users of coke in a mutually better position.

Mr. M. Wynter Blyth (Barnsley), in reply, said: The paper has been brought forward chiefly to raise an interest in the subject. Prof. O'Shea and I do not wish to lay down any definite statement as to what should be or what should not be. We want to encourage work on the subject, and all the remarks which have been made in criticism are very worthy of consideration.

Our work has extended over a period of nearly four years, and as a result we consider that for the purpose of washers which are constructed to wash coal for coking purposes the soundest and best standard is the ash content in the coke, combined with a sink-and-float test on the dirt. That is simply our own experience, and we have not come to that conclusion at all hastily. If somebody will bring forward facts to show that the sink-and-float test alone is better, I am certain that Prof. O'Shea and I will accept it.

The criticisms have been directed chiefly to the question of taking the ash as a standard, and secondly to the more or less large, bulky, and elaborate method of sampling. Mr. Dron has stated that collieries would have to employ a professor in order to carry out the tests suggested. I may mention that I have under my supervision at present three different washers, and we are carrying out these tests as routine work without the slightest trouble. We are testing the efficiency of the washer by the ash content of the coal. Only a very small sample need be prepared from the bunker. As a matter of fact, a bucket is filled with coal twice during the twenty-four hours by handfuls drawn from the coal passing into the stamper-box, and a final sample is drawn from this. The only thing which gives us much trouble is the dirt. We have to get a very large sample of dirt, which takes about twenty-four hours to dry properly. But, in order to obtain quick results, so as to keep the washer working properly, we do withdraw a small sample of the dirt and dry it quickly on a hot plate, and the results are known within an hour. In the case of a large sample, the tests are carried out in the twenty-four hours, which is only done if the result of a small sample or the ash in the coke is unsatisfactory.

From my experience of washers I think it is far more important to have good material to put in the washer and good men on the job than it is to have a special washer. My experience is that all the best types of washers are very good indeed, and that they only fail because the men in charge of them do not know how to work them; they have not proper advice from the laboratories, and the material which is sent to them is indifferent. I have one washer which sizes before washing and two washers which size after washing, and they are both equally good. We are washing the Fenton and Whinmoor Seams, which are very difficult seams to wash; we are at present producing a coke which has under 10 per cent. of ash, and are not losing more than 2 or 3 per cent. of coal at the outside in the dirt. Before the last washer was put up, the ash in the unwashed coke was 18 per cent. This will give some idea of the material that has been washed.

A good washer will pay over and over again for the time and trouble expended in getting good laboratory results. Any amount of trouble is worth going to in order to get fair samples. Hundreds and hundreds of pounds yearly can be lost if a washer is allowed to go wrong. I do not think that the amount of money which can be wasted in a short time by the inefficient supervision of a washer is realized.

I do not think it is possible to make a fair test on the organic matter in the refuse that is thrown away. The amount of organic matter in dirt varies enormously: it may be from quite a small percentage up to a very large one, and any guarantee based on the organic matter going away in the refuse combined with the ash in the coal would be extremely difficult to carry out.

THE EDUCATION OF COLLIERY MANAGERS FOR ADMINISTRATIVE AND SOCIAL RESPONSIBILITIES.

By WILLIAM MAURICE, F.G.S.

In the course of the discussion of Prof. F. W. Hardwick's paper on "The Training of Students in Coal-mining, with Special Reference to the Scheme of the Engineering Training Organization,"* the writer ventured to ask whether the general ideas upon which mining education has hitherto been planned are such as may be expected to produce the type of man for which the new times are calling.†

From an examination of almost any mining syllabus, it is difficult to discover the presence of any organic idea, of any clear intention to evolve a higher grade of colliery manager than is necessary to meet the current statutory requirements.

Whenever it is suggested that new subjects should be included in the curriculum, there almost invariably comes the answer that the time-tables are already overcrowded and that further additions are impossible. Occasionally there is another answer: "Your subjects are in the Arts Department"; and one gathers that technics and the humanities do not run together. The time-table difficulty, if it is a general one, can be overcome only by a reconsideration of teaching methods, and of the objects to be served. The non-professional mind wonders why students are not first taught *how to learn.*

The application of psycho-physiological methods of enquiry might reveal the fact that the art of teaching was extremely inefficient. Careful enquiry into the variety of subjects "taught" and in the methods of "teaching" might indicate both a superfluity of subjects and defects in methods.

Mr. John P. Houfton, speaking to the Midland Branch of the National Association of Colliery Managers as far back as 1895, said that the colliery manager "must be a geologist, a chemist, a mining engineer, a civil and mechanical engineer, an electrical engineer, an architect, a builder and sanitary engineer, and withal he must be a born leader of men." To isolate this sentence from the rest of his Address would be to misrepresent him, and to convey the impression that such a manager would be either an Admirable Crichton or a jack-of-all-trades. Mr. Houfton's Address is really one of the best expositions on the position and the responsibilities of the colliery manager that the writer can recall, and the following paragraph —indeed, the whole Address—ought to be in the possession of every mining student:—

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* *Trans. Inst. M.E.*, 1918-1919, vol. lvi., page 94.

† *Ibid.*, vol. lvii., page 21.

> "The colliery manager [said Mr. Houfton] must be a man of great tact, discretion, prudence, and common sense. He must have a great capacity for organization. He must be careful in judgment and prompt in action. He must possess great presence of mind, and be equal to every emergency—however unexpected and unforeseen—that may arise. In times of danger he must take his life in his hands and risk it for the sake of others." He must be ready to go "almost alone, in subterranean darkness, amidst foul gases, exposed to danger from falls of roof, from flood and from fire, to lead in the work of rescue."*

Mr. Houfton's is an admirable ideal. From the educational point of view, however, the idea seems to be implicit that the long list of technical accomplishments must be acquired in the school and in the mine, but that leadership, tact, judgment, and human qualities generally are natural faculties.

Is there not some reason for supposing that the technical ideal thus indicated is essentially that which holds the field to-day? Is it not also fairly evident that the human qualities are being, substantially, left to take care of themselves? Has there been any radical change in the spirit of mining education any time during the last twenty years? Are we not in reasonably close contact with fact when we say that the mining student of to-day is merely being taught perhaps a little more of each subject, but nothing which he has not always been taught?

Mining education is, of course, more than ordinarily difficult to organize, because mine managers come from all classes, and start with various degrees of what is known as "education," but is really only instruction. These men are called upon to exercise functions ranging from the control of a dozen men in a small hole in the ground to the direction of gigantic enterprises demanding the utmost attainable academic and administrative ability.

Between these extremes there lie positions calling for every gradation of skill. And yet, with so few exceptions that they do not materially affect the argument, everyone of these managers receives much the same order of training—a little more or a little less as the case may be—but no specific instruction deliberately based upon his expected vocation, or, at any rate, none which involves appreciable recognition of his human responsibilities.

What, roughly, is the course of training that the average mining student receives? He receives what is called "primary education" at a school—State, semi-private, or public, as the case may be—at some age between 16 and 18 goes to a Technical College, and pursues such studies as will enable him to pass the examinations prescribed by the Coal Mines Act. Concurrently, or otherwise, he works in a mine, sometimes according to a carefully-planned scheme, sometimes without any particular direction.

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* "Presidential Address" to the Midland Branch of the National Association of Colliery Managers, by John P. Houfton, 1895.

But always, it would seem, the sole conscious aim is to make him competent in a limited technical sense.* Eventually the student acquires the statutory qualifications, and may find himself the responsible manager of a colliery any time thereafter.

What is his position then? He discovers—as, in fact, he was already aware—that there is an engineer to look after everything mechanical; an electrician (responsible under the Coal Mines Act) to attend to electrical affairs; underground managers who often possess a whole world of such practical knowledge as cannot be acquired in the schools; surveyors who see to the preparation and upkeep of plans, and so forth; and perhaps several eminent experts to draw up large schemes or to advise on points demanding highly specialized knowledge and wide experience. In short, he finds that he is not really required to be a geologist, a chemist, an architect, etc., unless it be in a sort of complimentary sense.

What *is* essential is that he shall be possessed of a sound knowledge of the *principles* of all the arts and sciences that may come within his range. He is only required to be completely master of one art, and that is the art of mining.

In the acquisition of that art the schools can help him greatly, but the essence cannot be *taught* at all. It can be acquired only by long and intimate contact with Mother Earth, and not then unless there is some natural aptitude.

The new manager finds that his technical accomplishments, apart from knowledge of ordinary routine, are in relatively little demand. Frequently this is all to his advantage. If much were required at the beginning of his career, he would be well above the average if he found himself able to satisfy all these requirements.

The real work of the colliery manager of to-day, and more so of those who will follow, makes heavier demands upon his humanistic than upon his technical education. His business is to *manage* things; to organize work, and to see that it is performed by others with due regard to efficiency, safety, and satisfaction to all concerned; to inspect and supervise; to receive reports from and confer with members of the staff; to negotiate and determine hours of labour, rates of pay, rates of output, etc.; to attend to the fulfilment of statutory requirements; to meet deputations and to write reports; to judge misdemeanants, and reprimand or punish, not in accordance with ready-made ideas, but with a wise understanding of the probable cause of the shortcoming; to hear complaints and find right remedies. Briefly, the daily round and common task of the colliery manager is not so much to direct the inanimate forces of Nature as to guide and control those infinitely more complex living forces which find their expression in the mind and spirit of man.

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* It should be noted that this essay is an enquiry and not a criticism; its purpose is to elicit the facts, and, if they are as they appear to be, to suggest the desirability of a change of outlook.

The most important " machine " employed in industry is man. Every engineer is familiar with the conditions under which a contrivance will work most efficiently. He knows that a little oil, applied in the right place and at the right time, will prevent it from, so to say, " going on strike." He knows that metals and other inanimate objects may suffer from fatigue, and that they will break down if they are not rested. He makes careful studies of all these matters, and seeks to apply all human knowledge to obtain the conditions of maximum efficiency for any mechanism in which he may be interested.

What has he done so far, and what is he going to do, with regard to the one " machine " without which all others are utterly useless? The human machine has, it is true, been most extensively studied in the philosophic way throughout the ages. It is, however, only recently that man has been scientifically studied as a mechanism, that his physiological and psychological attributes have been made the subject of laboratory research as distinguished from merely intellectual analysis. The everyday engineer continues to use the human machine with considerably less intelligence than he exerts when he is inducing a nail to follow the directions of a hammer. His methods of lubricating this " machine " are empiric, not to say crude. His knowledge of human fatigue begins and ends with a general impression that some men are " born tired " and that the others don't do very much. As to "efficiency," the popular view is summed up in the phrase: the larger the pay, the smaller the output. And when he is considering how to get the best out of his men, his mind almost automatically drops the essential word and he finds himself thinking how to " get the best " of them. The common attitude is based on experience, and is therefore in a sense true to life. But it is far from being the whole truth, and the day is not far distant when it will be wholly untenable.

In the organization of work the manager finds himself confronted with demands, say, for shorter working hours. The workmen's representatives maintain that a reduction in time worked leads to increased output. The manager knows from practical experience that, while there is a strong show of reason in the claim, it is not in mining practice usually supported by results. His common attitude of mind is one of hostility to the proposed change, with a mental reservation that if it has to be made he will "take it out of them" somehow. No real leader ever thinks like this. If he were conversant with the works of such men as Prof. Jules Amar and Dr. Myers, and the extremely valuable reports issued during the war under the authority of the Home Office, he would undoubtedly view the problem from a new standpoint. Moreover, he would feel that it was probably in his power to so adjust the claim as to leave the commercial interests which it is his duty to protect with something to the good.

Mr. William Charlton has commented on the reduction in output of coal as the result of sporadic strikes and absenteeism.* Observing that the accepted method of protest against grievances—real, imaginary, and frivolous—is to stop work, and rightly indicating the advisability of immediate investigation into complaints and alleged grievances, Mr. Charlton would "like such a moral sense of responsibility to prevail amongst workers in our mines that they will achieve what is desired, and that persistent slackers would become Ishmaels in their midst."† To bring about such a result is a matter primarily of psycho-analysis, and then of the development of appropriate re-education. Not the least of the benefits that the war has brought in its train is the impetus given to the study of abnormal psychology as one of the most effective ways of treating patients suffering from shell-shock and allied war neuroses. The experience thus gained promises to be of incalculable value to educationists and those devoting themselves to the general problems of reconstruction. Hitherto, as Dr. Brock has observed, we have accepted, for example, the symptom known as "grousing," or the allied condition of "standing on one's dignity," as just a human attribute which irritates or amuses us according to our individual point of view.

"The psychologist probes into the patient's subconsciousness and finds 'grousing' to be a form of self-drugging, of preserving one's self-confidence, of attempting to compromise with life. And those who "stand on their dignity" are merely instinctively attempting to bolster themselves up by supports . . . . which do not call for effort on their part." "They delude themselves into believing that they are 'people of consequence'; they actively suppress the suggestion that they are not, but at the same time they live in a constant condition of half dread lest the submerged truth should out" . . . . "they are not merely hypersensitive and thin-skinned to the last degree; they are *ergophobic*."* Dr. Brock has also made some interesting remarks on subconscious malingering, on the influence of environment, on people being " up against " one another, and so on, all of which illustrate the really practical bearing of modern psychology on industrial life.

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* "Presidential Address," *Trans. Inst. M.E.*, 1918-1919, vol. lvi., page 15.

† *Ibid.*, page 17.

A reliable working knowledge of *psycho-physiology* would help the manager through innumerable difficulties. He would see what was wrong with scientific management, as popularly expounded, and very soon find himself convinced that the efficiency of the human machine *can* be enormously increased. And this, not, as the earlier and a section of the present exponents of scientific management would increase it, by seeking to convert an immortal soul into a mere mechanism, but by means which are definitely contributory to the workman's spiritual and physical well-being.

The study of the coming science of *industrial psychology* would open the student's eyes to new adventures in research, and leave him more than ever satisfied that, for colliery managers in particular, " the proper study of mankind is man." If he could go through a wisely-directed course in *social psychology* and in *social science* generally, he would approach his life's work with an entirely new outlook, and would be far less likely to set up—or to permit others to set up—those petty irritations which lie at the root of so many industrial disputes.

All these studies are attractive: they are pre-eminently humanistic; and, since the pursuit of them inevitably leads the student into innumerable and enchanting bypaths, he is almost automatically set going along a path of great national service.

There are strong reasons why the training of colliery managers should be much broader and more thorough than it is. In these days every manager is brought into close contact with social forces of universal range.

> " There is no longer that quiet satisfaction with the customary methods of doing things that characterizes the epoch of accepted order. Those who are sensitive to signs of change know that society is preparing to take a step forward; they feel that the old watchwords no longer have the same authority and that men are consciously and unconsciously reaching out to new ideas and purposes and adjusting themselves to new methods. It is as though society had accomplished certain things with fairly appropriate institutions and habits, had enjoyed the benefit for a time and was then reaching out for something finer and more adequate."†

This is a time of national rebirth. We are witnessing the beginnings of a veritable twentieth-century renaissance. Innumerable schemes for reconstruction are being propounded on all sides. They will all fail in so far as they prove to be running counter to the spirit of the times.

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* *The Neurasthenic in War and Peace*, by Arthur J. Brock, M.D. (Edin.), pages 3-4.

† *The Next Step in Democracy*, by R. W. Sellars, Ph.D., pages 1-2.

"Set mankind in motion towards an end it can realise and achieve and you have introduced a motive of permanent discord into society. Set it in motion towards an end too lofty ever to realize and you have struck the note of unity. This is the difference between the spiritual motive and the material. The spiritual motive unites society, the material motive divides it."*

It is suggested that such studies as are herein indicated would serve the double purpose of contributing to immediately "practical" ends while providing that note of idealism without which no one can be said to be truly "educated." It is not safe to accept Agoraia as the supreme goddess of reconstruction.

Colliery managers occupy very exceptional positions in the industrial hierarchy. There are only about 1,500 managers in control of over a million miners. If we assume that one million miners represent about two million families, we find that this comparatively trivial number of individuals are in a position to influence the lives of perhaps one-quarter of the total number of families in the country! The figures are not statistically accurate, but they approximate to the facts sufficiently to indicate the immense national influence that could be exerted if each manager made a point of rendering whatever form of social service was compatible with his temperament and abilities.

The *quality* of that service would be increased beyond calculation if all were trained in the *principles of citizenship* and imbued with the essential elements of "that intellectual, spiritual, and practical adventure which is called *sociology*." Actually, the colliery manager's social possibilities are much greater than has been so far suggested, for each is, or should be, the acknowledged leader of the local community whose industrial energies he directs. He is the local symbol of authority and power. If he is aware of, and sympathetic towards, the present undoubted transition stage from individualism to all that is involved in the spirit of community, he has only to lead, and he will be assured of a loyal and even enthusiastic following.

It is not, of course, for a moment implied that the present generation of managers fail in the fulfilment of their social obligations. On the contrary, there are few, if any, acting managers who do not devote the greater part of, and sometimes all, their limited spare time to various forms of social service. As county and city magistrates, as councillors, as chairmen of local boards, as members of education committees, as organizers of sports and recreations, and in multitudinous other ways they more than do their share.

But what a different world it would be if all the colliery managers of the future were able to approach these social activities with a clear knowledge of what is and what might be! If they all went to work with an ideal in their minds and the resolution to achieve it, or, at least, to exert their influence in the direction of its achievement! If they sat on education committees knowing the teaching of such people as Edmond Holmes, Thiselton Mark, Ellen Key, and Stanley Leathes! If they did not sit upon judicial benches until they had read Galsworthy! If when they were considering town-planning schemes they could bring to bear on the problems the vision of a Patrick Geddes!

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* *Europe Unbound*, by Lisle March Phillipps, page 150.

The purpose of this essay is to be suggestive rather than explicit, and perhaps enough has been said to serve that object.

> "New times demand new measures and new men;
> The world advances, and in time outgrows
> The laws that in our fathers' days were best;
> And, doubtless, after us, some purer scheme
> Will be shaped by wiser men than we,
> Made wiser by the steady growth of Truth."
>
> —*James Russell Lowell.*

The PRESIDENT (Mr. G. Blake Walker): Many of us will be in agreement with what the author has stated. We endeavour in our own sphere to ameliorate the conditions of the working miners. But we have to contend with an immense amount of old-fashioned prejudice, and, I might say, ignorance, which is always present. It is no use ignoring the fact that these conditions exist, and that no amount of goodwill on our part will do away with them. There is a tremendous lot of the jackass in human nature, and it is not wanted in the collier. Pope said, "Whatever is, is right"; but I think that the colliers, especially some we know of, are quite of the opposite opinion, and believe that whatever is, is wrong. By all means let us endeavour by social activities to dispel that unfortunate disposition to distrust everything which comes from those who are in the position of managers and owners. We are suffering terribly from it now, and what the end of it will be we do not know. I am sure that we must get rid of that distrust and illwill before we can accomplish anything for the good of the profession.

Mr. JOHN GIBSON (Kilmarnock) wrote: I submitted in 1915 a paper on somewhat similar lines to the Publications Committee of the Mining Institute of Scotland. It was considered unsuitable, and, after considerable excision and alteration, it was read under the title of "Some Notes on the Education of the Colliery Manager."* Mr. Maurice's paper, therefore, seems to me to be a significant index of the rapidly changing times in which we live, and a far-sighted survey of the uncharted social sea into which civilization seems to be sailing. For many years the position regarding the colliery manager has been, in my opinion, this: He was and is trained to take care, say, of a venture in which £100,000 has been sunk. He knows a good deal about physics, chemistry, mathematics, geology, and various other sciences, but he has been taught nothing regarding men. Yet in a £100,000 venture the men engaged probably have an exchange value (if such a term can be properly used in this connexion) of £300,000 and an intrinsic value of an infinite incalculable amount. The contrast does not end here, because the installation, use, and care of machinery is a simple elementary mechanical task compared with the handling and getting the best use of the men. How many strikes might be avoided, for example, if both the colliery manager and the miners' agent had a knowledge of the humanities?

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* *Trans. Inst. M.E.*, 1914-1915, vol. xlix., page 195; discussion, vol. xlix., pages 200, 341, and 515; and 1915-1916, vol. l., page 33.

If it be postulated that the manager should be first a leader of men, how can that be taught? I submit that studies on the following lines will be helpful:—

(1) History. Take three very dissimilar historical characters who have succeeded, and three who have failed. In the first category I would put Louis XI., Queen Elizabeth, and Napoleon; in the second, Philip the Bold, Charles I., and Louis XVI. I submit that the man who has made a philosophical study of these will handle a few hundred pitmen with ease and success.

(2) Logic. By this I do not mean the logic of the schools, but a firm grasp of the elements and a complete knowledge of the fallacious tendencies of the human intellect. It is sad to meet so many otherwise estimable people who say that they hold certain opinions when in reality they themselves are possessed by certain prejudices.

(3) Economics. Every administrator finds himself confronted daily with as many important matters as would keep him engaged for months. Each of these tasks has some degree of importance and urgence. The most urgent should be done first. The muddling man is simply one who frequently errs in deciding on the relative urgency of the tasks confronting him. In order to decide well, certain economic facts relating to time and money in the light of the set of circumstances surrounding each particular case must be considered and a decision immediately arrived at. Every case, indeed, in which one penny in wages, machinery, or stores is at stake is an economic problem, but at the present time the man who handles them has no economic training.

(4) Literature. This is at once the great source of practical wisdom, and the most glorious relaxation for the practical man. How trivial our own little personal worries, and how faint-hearted our bravest efforts seem, when we compare them with the valiant heart of Sir Walter Scott when faced with financial disaster, or with Robert Louis Stevenson's cheerful optimism in his life-long struggle with disease and impending death.

Mr. Maurice does not outline any particular set of subjects of study, but I presume that his ideal generally is to make the education of the manager wide and philosophic—not narrow and specialized, as at present. If this presumption is correct, I am entirely in agreement with him.

Mr. GERALD T. NEWBOULD (Earl Fitzwilliam's Collieries) wrote: As a student, Mr. Maurice's paper appeals to me with particular interest. Education looked at in one way is perhaps skill in thinking, for the more trained one's mind becomes, the easier all forms of brainwork appear. Natural aptitude is, unfortunately, rather scarce, but where it does exist it develops quickly, and feeds itself in a like manner to that of a fire caused by spontaneous combustion.

Doubtless there are many forms of valuable education apart from ordinary routine instruction. Prof. W. G. Fearnsides, at the inaugural meeting of the Midland Junior Mining Engineers' Society, said that "Good-tempered discussion among friends increases both the quickness of one's wit and the breadth of one's understanding more rapidly than any other form of education known to man."

Mr. Maurice, I think, rather underestimates the responsibility that a manager would feel if he left everything to his engineer, under-manager, surveyor, etc., although undoubtedly a great portion of a manager's time is spent in administrative duties; and, as Mr. Maurice suggests, a wisely-directed course in social psychology would be seemingly of benefit to those who are still students.

Mr. WILLIAM MAURICE (Sheffield), in reply, wrote: I had hoped that there would be considerable discussion on the paper. It is precisely because there does exist "an immense amount of old-fashioned prejudice and . . . . ignorance," as the President remarked, that the paper has been written. It seeks to go to the root of social reconstruction, to point out that mere goodwill is in itself useless, and to show that the solution of the problem lies in the discovery of the causes of prejudice. Politicians talk round and round such topics as industrial unrest, and invariably arrive at the starting-point. Psychologists say that it is possible to discover the basic causes of almost any mental attitude, and considerable work of the highest economic and social value is already on record. When the cause of any effect is accurately known, the remedy, if not actually in sight, is not far off.

Intellectual honesty should be brought to bear on such questions as the proposal to teach politics, by which, of course, is meant politics in the Aristotelian sense, but this is a point which has always been shirked. Its consideration involves facing facts, and nothing annoys ordinary persons so much as facts. It would seem that the whole business of Government and half the business of life are absorbed in dodging facts. If this be true, there is not much prospect of the nation taking a definite step forward. Our present educational system is not producing satisfactory results, and it is most important that this truth should be widely recognized.

Mr. John Gibson's aims appear to coincide with my own. I would rather, however, indicate desiderata, and the various ways by which these may be attained, than formulate definite courses of study. It is not uniformity that is wanted, but an educated diversity of thought. I do not suggest, as Mr. Gerald T. Newbould seems to think, that a manager should leave technical matters to his staff. The main point raised by me was that technical education is indifferently taught, and that certain subjects, which appear to be of at least equal importance, are not taught at all. I also clearly suggest that a carefully-planned scheme of education in social and economic subjects, *for working miners as well as for mining students*, would tend to steady any inclinations towards violence, and assist industry to move sanely along the path of progress.

DISCUSSION OF MR. T. LINDSAY GALLOWAY'S PAPER ON "A METHOD OF DETERMINING THE MAGNETIC MERIDIAN AS A BASIS FOR MINING SURVEYS."*

Mr. T. **Lindsay Galloway** (Campbeltown) wrote: With reference to the employment of a copper damper as a means of checking the oscillations of the mirror, I desire to correct an impression that might be conveyed by my remark on page 235 (Vol. LVI.) that neither Dr. Chree nor Prof. Tanakadate makes use of a copper damping device. It would be more correct to say that neither of these gentlemen depends upon, or attaches much importance to, the use of a damper for the particular kind of observations contemplated in the paper. The instruments at Kew are all more or less damped, and Dr. Chree states in a letter to me, dated April 30th, 1919, that—

> "the magnetograph magnets—including the declination one—have all massive copper dampers, and the magnet boxes of all the old declinometers, intended for declination purposes only, are of massive copper. . . .In the case of the ordinary modern unifilar magnetometer, intended for horizontal force as well as declination observations, the base of the box is copper or brass, and does a certain amount of damping. . . . . For mere absolute observations of declination—assuming there is no artificial disturbance from electric trams or railways—there is not really much, if any, advantage in heavy damping."

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* *Trans. Inst. M.E.*, 1918-1919, vol. lvi., page 222.

Instead of using three tripods, as described in the paper, a theodolite with a centering movement may be employed. It is placed directly in front of the reflector, so that its own plumb-line can be seen in the mirror. By means of the centering device and the tangent screw of the horizontal circle, the reflected image of the plumb-line and the cross-lines in the telescope can be brought into exact coincidence. If the instrument is now turned through a right-angle, its centre-line will be parallel to the face of the mirror. The method described in the paper, however, admits of great latitude in the choice of the points *A*, *B*, *C*, and either *A* or *C* may be a point in a permanent base-line to which we can return with certainty again and again. In the second method we may doubtless return to exactly the same fixed point in setting up the instrument; but, if we subsequently shift it by the centering device, in order to bring the image of the plumb-line into coincidence with the cross-lines, a slight error may be introduced.

Mr. George Spencer, in some interesting experiments which he has been making, some of which I had the pleasure of seeing, fixes a scale on the object-end of the telescope. By observing the reflected image of the scale, and knowing the distance from the mirror, it is easy to calculate the exact amount by which the line of vision deviates from the normal, and thereby avoid the necessity of shifting the theodolite. Among other modifications proposed by Mr. Spencer is a much heavier magnet, and a suspension consisting of a number of parallel silk fibres. In this respect he goes to the opposite pole to Prof. Tanakadate, who, as already stated, uses an extremely small and light magnet suspended by a spider-line, which he finds to be reliable in practice. Other magnetometers have been made in which a very fine ribbon of phosphor-bronze, and others, again, in which a quartz fibre, has been used as the suspension. Experience is needed to determine what material is most suitable in the present case. I am now in communication with an experienced firm of instrument-makers, with a view to constructing a magnetic reflector specially adapted to mining conditions.

The gyroscopic compass, now much used in the Navy, and familiarly known therein as the "Sperry," suggests the possibility of a new method of determining directions underground independently of the earth's magnetism. Those who have seen this compass will be aware that in its present form it is both costly and complicated, and it remains to be seen whether, supposing these drawbacks were eliminated, its indications would be sufficiently accurate for the requirements of the surveyor. But it is an interesting possibility that an instrument of this class might be applied in mining practice as a direct means of determining the true meridian underground.

PROF. F. W. HARDWICK'S REPLY TO THE DISCUSSION ON HIS PAPER ON "THE TRAINING OF STUDENTS IN COAL-MINING, WITH SPECIAL REFERENCE TO THE SCHEME OF THE ENGINEERING TRAINING ORGANIZATION."*

I am much gratified by the very interesting discussion which my paper has raised, and offer my thanks to all those who have contributed to it. The main object of the paper was to invite The Institution of Mining Engineers to issue a statement showing the existing arrangements by which a boy could enter the profession. I do not agree with Mr. F. Oxley as to the advisability of suggesting a standardized course of instruction, nor do I think it is possible to evolve a counsel of perfection. As the discussion on this and on other papers on mining education show, there is a great variety of opinion on the subject. Nor is this individual difference of opinion the only point to be taken into account: as Prof. William Garnett remarks, the training should be arranged so as to suit the boy's capacity. But unless a parent has before him a synopsis of the requirements of the profession, and the various courses of training open to candidates for the profession, it is not easy for him to be sure what is the best course to choose. It seems to me that to furnish such information would be a very useful act on the part of the Institution. Mr. William Maurice has pointed out the difficulty of obtaining special information on various subjects, and this is a case in point.

I do not understand why Mr. H. Eustace Mitton should delegate this duty to Institutions and Colleges—that is if by Institutions is meant teaching Institutions—because these bodies have their own work of teaching to do. The work could be done more easily by a central bureau, which could be fully informed by each branch of the engineering profession as to its requirements, and as to the various methods of training available for students. An arrangement of this kind would make for efficiency, and would save a great deal of needless labour.

The need for specialization in certain branches of the mining industry, alluded to by Mr. W. D. Lloyd and by Mr. Mark Halliday, seems also to call for some organized attempt to advertise the existence of this need, so that attention could be directed to it, and the studies of young men destined for any particular branch could be conducted on suitable lines.

As Prof. Sir W. J. Ashley has pointed out, the collection of the necessary information as outlined in the paper is a very simple matter. The great point is that it should embrace all important points, should be easily comprehensible by a person not connected with coal-mining, and should be accurate. I agree with Sir W. J. Ashley that when such a statement has been prepared it will very likely lead the way to suggestions as to what education is *desirable* for those who propose to take up coal-mining as their profession. A report on the lines suggested by Mr. George Hunter would be of great interest, and would be of practical utility in view of the provisions of the Education Act, 1918.

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* *Trans. Inst. M. E.*, 1918-1919, vol. lvi., page 94; discussion, vol. lvi., pages 101, 119, 134, 163, 188, and 197; and vol. lvii., pages 20, 38, 136, and 172.

I have to thank Prof. Henry Louis for his answer to the question respecting practical work in the vacation. I do not think that there is much difference between our views on school education. I quite concur in the teaching of the ordinary school subjects, including Latin, and one modern language, but I think that more attention should be paid to the scientific subjects which I have mentioned in the later stages of their school career in the case of boys who propose to become engineers. As Prof. L. T. O'Shea has pointed out, special instruction is given to boys who intend to enter for the army and for the civil service. I think that Prof. Louis's remarks respecting the difficulty which is experienced in some cases by boys who wish to get taken on at a colliery after their College course is finished are of great interest, and I hope that some practical notice of this subject will be taken—a free apprenticeship at a colliery would prove a great incentive to a boy to work hard whilst at College.

Mr. J. H. W. Laverick's suggestion that a student in his first year at the colliery should take surveying is excellent, and goes far to remove the objection to the year at a colliery which many members think should be interposed between a boy's school career and his training at an "approved" institution, though I agree with Prof. O'Shea that there is the danger that the habit of study may be lost, unless steps are taken to prevent this.

In reply to Mr. William Maurice's questions, the publications of the Engineering Training Organization can be obtained from the Engineering Training Organization Office, c/o The Chief Engineer, Daimler Works, Coventry; the Report of the Institution of Civil Engineers is published by Messrs. William Clowes & Sons, Ltd., of 31, Haymarket, S.W. 1.

Prof. Sir John Cadman and Mr. J. T. Stobbs have mentioned the hereditary character of the mining profession, but I think that this is a characteristic of most other professions—in fact, I am greatly in favour of the son following in the father's footsteps. In some cases, however, the son may have a definite inclination for some other profession, or, where there are several sons, the father may hesitate about putting all his eggs in one basket. In any case this does not seem to be a valid objection to the suggestion made in the paper that the Institution should indicate the various lines on which the training of a mining student might be conducted. Prof. Louis suggests that information can be obtained from any of the Mining Colleges, but this seems to commit the parent to one course, namely, to enter his son through a University or College; and if only one educational Institution is consulted, the course adopted would be the one favoured by that Institution. Prof. Louis also suggests that if a central agency is needed, it might be established in conjunction with the Mines Department. There seems, however, to be no necessity for The Institution of Mining Engineers to draw up its information respecting the training of mining students with reference to any outside body; if such information were made available, it could be furnished to anyone who applied for it.

Prof. Sir John Cadman, Prof. Louis, and Mr. H. Eustace Mitton have pointed out that the paper applies chiefly to those students who are preparing for the higher branches of the profession. This was necessarily the case, since the principal object of the paper was the collection of easily accessible information which might be useful to students who had been educated at a public or secondary school—that is, to the articled-pupil class.

It cannot, however, be said that the important subject of the technical training of students already engaged in coal-mining has been neglected entirely—that is, of the working miner or colliery official. The fact that technical education of this kind is already provided by local educational authorities is touched upon in the paper, and allusion is made to the scheme put forward by Mr. Berriman for the benefit of the engineering trade apprentices. The organization of this class of education is, however, too wide a subject to be treated generally in a paper, except, perhaps, in outline; it is a matter for each district to deal with individually, since the facilites for education may vary in different parts of the same coalfield. In my Presidential Address* to the Midland Institute of Mining, Civil, and Mechanical Engineers in 1912 I gave a brief outline of the way in which this problem had been solved in the coalfield in the neighbourhood of Sheffield working under the Coal Mines Regulation Act, 1887. Doubtless since 1912 the scheme has been changed and improved to meet the altered conditions brought about by the Coal Mines Act of 1911; but, judging by the success which has attended many of the students who have received their technical training under that scheme, it was at least up to the requirements of that period.

If, however, I have understood correctly the scheme outlined by Mr. Berriman, it appears to be something wider than most existing schemes—a scheme which will enable a young man of ability to pass from part-time to full-time education while still engaged in manual work. Mr. Berriman divides the apprentices into five classes (*a*), (*b*), (*c*), (*d*), and (*e*), according to the training which they have received at school, and to the age at which they enter on their industrial occupation. Classes (*d*) and (*e*) are outside the scope of this portion of the subject; they are suited rather to an engineering pupilage than to apprenticeship. Classes (*a*), (*b*), and (*c*) include boys who enter the industry at 14 from an elementary school, and boys who enter at 16 from a secondary school; these boys, while working as apprentices, are to have part-time education, and those who show promise will be advanced by stages of selection, and be given opportunities of widening their experience. The ultimate goal appears to be a limited pupilage combined with a " sandwich " course at a University or College, of a type suited to non-matriculated students.

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* *Trans. Inst. M.E.*, 1912-1913, vol. xliv., page 425.

The question then arises whether a student of ability who has been educated in an elementary school and in part-time courses is sufficiently trained to enable him to avail himself of an opportunity to enter a full-time course at a University or College, if such opportunity should be presented to him, or whether some training at a secondary school is necessary as an introduction to the higher training. Dr. Ripper, in his paper on " University Education in Relation to Mining Engineering "* lays stress on the importance of attendance at a secondary school in the case of boys who are preparing for industrial training. In the *Memorandum on the Teaching of Coal Mining in Part-time Schools*, issued by the Board of Education,† the advantage of a secondary-school education is also mentioned, but the possibility that a few part-time students may make their way to full-time institutions by means of scholarships is indicated, and the suggestion is made that the number of such students may be increased by improving the character of the instruction provided in part-time schools. This point has also been raised in the discussion by Prof. Sir John Cadman and Prof. O'Shea.

As Mr. E. B. Wain remarks, the Education Act, 1918, ought to assist materially in the furthering of schemes for this class of technical education.

There is a point in connexion with the discussions on papers on educational subjects which I regret, namely, that those members who have obtained the Certificate of Competency by practical work in the mine and by the aid of part-time instruction seldom take part in them. The experience gained by such members ought to be of great value to those who desire to improve existing schemes of mining education.

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* *Trans. Inst. M.E.* 1917-1918, vol. liv., page 287.

† ii., " Courses of Instruction," page 6.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM AUGUST 3RD TO AUGUST 30TH, 1919, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of Week.	Day of Month.	Magnetic character.	Intervals in hours (Greenwich mean time). 0h. to 2h.	2h. to 4h.	4h. to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h.	18h. to 20h.	20h. to 22h.	22h. to 24h.	Mean for day.
	August.		14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
Sun. ...	3	0	36′·0	34′·5	33′·5	35′·0	35′·5	38′·5	45′·5	46′·5	44′·5	42′·0	40′·5	38′·5	39′·0
Mon. ...	4	0	37·5	38·0	36·5	34·5	36·0	41·5	45·0	46·0	44·0	40·5	41·0	40·0	40·0
Tues. ...	5	0	38·5	37·5	37·0	36·0	37·5	44·5	49·0	45·5	43·0	41·0	39·5	37·5	40·5
Wed. ...	6	0	36·5	36·5	35·5	37·0	38·5	42·0	45·0	44·0	41·5	40·5	39·5	39·5	39·5
Thur. ...	7	1	38·5	38·0	35·5	34·0	37·5	42·5	45·0	43·0	42·0	39·0	38·0	37·0	39·0
Fri. ...	8	0	37·0	36·5	35·0	34·0	37·5	43·5	48·5	48·5	42·0	39·5	38·5	38·5	40·0
Sat. ...	9	0	40·0	38·5	36·5	34·5	37·5	44·5	47·5	44·5	39·5	38·0	39·0	39·5	40·0
Sun. ...	10	0	39·0	38·0	35·5	34·0	37·5	43·5	47·5	46·0	42·0	40·5	40·0	39·5	40·5
Mon. ...	11	2	39·5	38·0	36·0	39·0	29·5	44·0	51·0	56.5	62·5	51·5	42·5	43·0	44·5
Tues. ...	12	2	46·5	40·0	23·0	24·0	34·5	44·0	48·0	47·0	45·0	41·5	39·5	39·5	39·5
Wed. ...	13	0	39·0	38·0	37·0	36·5	38·0	42·5	45·0	41·0	38·0	38·5	38·5	38·5	39·0
Thur. ...	14	0	38·0	37·5	37·5	34·5	36·0	42·0	47·5	44·5	41·5	39·5	39·0	38·5	39·5
Fri. ...	15	0	37·5	37·5	36·5	34·0	35·0	40·5	47·5	47·5	42·5	40·0	39·5	35·5	39·5
Sat. ...	16	1	32 5	35·5	37·0	35·5	37·5	43·5	48·5	47·0	43·0	41·5	39·0	39·0	40·0
Sun. ..	17	1	37·0	35·5	35·0	34·5	37·5	42·5	48·5	47·5	43·0	41·0	39·5	38·0	40·0
Mon. ...	18	0	39·0	40·0	38·5	38·0	39·5	43·0	48·5	46·5	41·5	40·5	41·5	38·5	41·0
Tues. ...	19	1	34·5	37 0	40·5	38·5	40·0	44·0	47·5	47·0	44·0	39·0	36·0	39·5	40·5
Wed. ...	20	1	39·5	37·5	38·5	34·0	36·5	43·0	47·0	45·0	40·5	39·0	39·0	41·0	40·0
Thur. ...	21	0	43·0	40·5	36·5	33·5	35·5	43·0	47·0	43·5	40·5	40·5	41·0	41·0	40·5
Fri. ...	22	0	40·5	40·0	39·0	37·0	38·5	45·5	47·5	44·0	40·0	40·5	41·0	41·0	41·0
Sat. ...	23	0	41·0	38·5	36·0	35·5	39·5	45·5	48·0	45·0	42·0	42·0	40.5	39·5	41·0
Sun. ...	24	0	37·5	33·0	36·5	36·5	38·5	43·5	47·5	44·5	41·0	41·0	40·0	39·5	40·5
Mon. ...	25	0	39·0	38·5	37·0	34·0	36·0	43·5	46·5	44·5	40·5	40·0	40·0	37·5	39·5
Tues. ...	26	0	35·0	34·5	33·5	34·0	38·5	47·0	53·0	49·5	43·5	42·0	40·0	39·5	41·0
Wed. ...	27	0	39·0	38·0	35·0	37·5	39·0	43·5	46·0	44·0	41·5	40·5	40·0	39·0	40·0
Thur. ...	28	0	39·0	39·0	37·0	35·0	38·0	43·0	48·0	48·5	44·5	42·5	38·5	34·0	40·5
Fri. ...	29	0	35·0	36·0	34·5	34·5	38·5	47·5	50·0	45.5	41·0	39·0	39·0	39·0	40·0
Sat. ...	30	0	38·5	38·5	38·5	36·5	38·0	44·0	47·5	44·0	41·0	40·0	39·5	38·5	40·5

Diurnal Inequality (i.e., departure from mean value for day).

	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.
August, 1918 ...	−1′·2	−1′·3	−1′·5	−2′·5	−3′·7	−4′·6	−5′·1	−4′·9	−3′·2	−0′·4	+3′·1	+6′·0
July, 1919 ...	−1·6	−1·5	−1·9	−2·5	−3·9	−5·0	−5·7	−5·8	−4·4	−1·8	+1·3	+4·4
July, 1918 ...	−1·1	−1·3	−2·0	−2·7	−3·9	−5·2	−5·2	−4·7	−3·4	−1·1	+2·1	+4·9

	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
August, 1918 ...	+7′ 5	+7′·1	+5′·6	+3′·5	+1′·5	−0′·1	−0′·8	−0′·5	−0′·7	−1′·4	−1′·3	−1′·1
July, 1919 ...	+6·6	+7·4	+6·7	+4·9	+3·1	+1·5	+0·7	+0·4	0·0	−0·6	−0·9	−1·2
July, 1918 ...	+6·3	+6·5	+5·6	+4·2	+2·5	+1·2	+0·1	−0·4	−0·3	+0·5	−0·7	−0·9

Mean Value for Month.

August, 1918.	July, 1919.	July, 1918.
14° 49′·0.	14° 40′·8.	14° 50′·4.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G.M.T.

Character "0" means a day wholly free from any but small disturbances.

" "1" " " part or all of which is moderately or considerably disturbed.

" "2" " " part or all of which is highly disturbed.

The normal value for an hour is the mean declination for that hour in the month, derived from quiet days only, or from all days excluding those of character "2." On a day of character "0" declination at any hour will usually be within about 3′ of the normal. On a day of character "1" the departure from the normal will usually not exceed 5′, but it may occasionally be as much as 10′, or even more. On a day of character "2" the departure from the normal will seldom exceed 20′, but departures of 30′, or even on extreme occasions of 1° or more, may occur.

The above values were obtained from measurements made after "smoothing" the curves.

MEAN MAGNETIC DECLINATION FOR EACH TWO-HOUR INTERVAL FROM AUGUST 31ST TO SEPTEMBER 27TH, 1919, AS RECORDED AT KEW OBSERVATORY, RICHMOND.

Day of Week.	Day of Month.	Magnetic character.	0h. to 2h.	2h. to 4h.	4h. to 6h.	6h. to 8h.	8h. to 10h.	10h. to 12h.	12h. to 14h.	14h. to 16h.	16h. to 18h	18h. to 20h.	20h. to 22h	22h. to 24h.	Mean for day.
			Intervals in hours (Greenwich mean time).												
	August		14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+	14°+
Sun. ...	31	0	38′·0	38′·0	37′·0	36′·0	38′·5	45′·0	48′·5	45′·0	41′·0	39′·5	38′·5	38′·0	40′·5
	Sept.														
Mon. ...	1	0	37·5	36·5	35·0	35·5	38·0	41·5	44·0	43·0	41·0	39·0	39·0	39·0	39·0
Tues. ...	2	1	37·5	37·0	36·5	36·5	38·5	41·5	45·5	47·0	46·0	40·5	32·0	28·5	39·0
Wed. ...	3	0	31·0	36·0	36·0	35·5	36·5	42·0	47·5	47·0	42·5	33·5	34·5	33·0	38·5
Thur. ..	4	0	32·0	31·5	36·5	36·0	40·0	46·0	49·0	47·0	40·0	37·0	36·5	36·5	39·0
Fri. ...	5	0	37·5	37·0	37·5	35·5	36·0	42·5	46·0	44·0	40·0	39·0	39·0	36·5	39·0
Sat. ...	6	1	37·5	36·0	38·0	39·0	37·5	41·5	46·0	45·0	40·5	36·0	36·0	36·5	39·0
Sun. ...	7	1	30·5	30·5	34·5	33·5	35·0	42·0	44·5	44·0	41·0	37·5	38·5	39·5	37·5
Mon. ...	8	0	38·5	37·5	36·5	36·0	37·0	43·0	44·0	41·5	40·0	38·5	37·0	37·0	39·0
Tues. ...	9	1	37·5	37·0	36·0	34·0	36·0	44·0	47·5	45·5	39·5	34·0	34·0	34·0	38·5
Wed. ...	10	1	36·5	35·5	34·5	33·5	35·0	42·5	45·5	43·5	40·5	40·5	37·0	34·5	38·0
Thur. ...	11	0	36·0	36·5	36·5	35·5	38·5	44·5	47·5	44·0	40·0	38·0	38·0	38·5	39·5
Fri. ...	12	0	38·5	38·5	37·0	35·0	36·0	42·5	45·5	43·5	40·0	39·5	39·0	38·5	39·5
Sat. ...	13	1	38·0	37·0	36·5	35·5	36·0	42·0	47·0	45·5	40·5	36·0	37·0	35·5	39·0
Sun. ..	14	1	37·5	38·0	36·5	35·5	38·0	43·5	46·5	45·0	40·5	39·5	38·0	38·5	40·0
Mon. ...	15	1	38·5	39·0	38·5	38·0	38·5	43·0	46·0	45·5	43·0	39·5	38·5	37·0	40·5
Tues. ...	16	1	37·0	36·5	41·0	39·0	38·5	42·0	45·0	44·0	40·5	38·0	38·0	38·0	40·0
Wed. ...	17	1	38·5	40·0	37·0	36·0	38·0	42·5	44·5	42·5	40·5	38·0	38·0	37·5	39·5
Thur. ...	18	1	39·0	38·5	38·5	35·5	36·0	41·0	44·0	43·0	41·5	39·5	37·5	31·0	38·5
Fri. ...	19	2	32·0	31·0	36·5	42·0	43·5	48·0	51·5	50·5	41·5*	34·0*	33·5*	24·5*	39·0
Sat. ...	20	2	30·5*	31·0*	38·5	38·5	39·0	43·0	46·5	45·0	41·5	40·0	37·5	36·5	39·0
Sun. ...	21	2	35·0*	36·0*	37·5	40·5	37·5	42·0	44·5	42·5	40·0	39·0	35·5	33·5	38·5
Mon. ...	22	1	35·0	36·0	38·0	37·0	36·5	43·5	45·0	42·0	38·5	36·5	34·5	33·5	38·0
Tues. ...	23	1	35·5	37·0	36·0	34·5	35·0	41·5	45·5	44·0	42·0	38·5	37·0	36·5	38·5
Wed. ...	24	2	26·0*	29·5*	35·0*	39·0*	37·0	40·5	47·0	47·0	45·5	39·5*	39·5	37·5	38·5
Thur. ...	25	1	35·0	34·0	35·0	36·0	39·0	43·0	45·5	47·0	42·0	38·0	38·5	37·0	39·0
Fri. ...	26	0	36·5	36·5	37·0	36·5	37·0	41·5	45·5	44·5	40·5	39·0	38·5	36·5	39·0
Sat. ...	27	0	36·5	36·0	36·5	36·0	36·0	40·0	44·0	43·0	40·0	38·5	38·0	38·0	38·5

Diurnal Inequality (*i.e.*, *departure from mean value for day*).

	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.
September, 1918 ...	−1′·2	−1′·7	−2′·4	−2′·9	−2′·9	−2′·9	−3′·8	−3′·8	−2′·3	+0′·4	+4′·3	+6′·6
August, 1919 ...	−2·2	−2·3	−2·4	−3·0	−3·4	−4·5	−4·9	−4·6	−2·9	0·0	+3·1	+6·0
August, 1918 ...	−1·2	−1·3	−1·5	−2·5	−3·7	−4·6	−5·1	−4·9	−3·2	−0·4	+3·1	+6·0

	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
September, 1918 ...	+7′·1	+6′·3	+4′·8	+2′·5	+0′·9	−0′·1	−1′·0	−1′·4	−1′·7	−1′·9	−1′·9	−1′·5
August, 1919 ...	+7·3	+7·3	+5·6	+3·3	+1·6	+0·7	+0·3	−0·1	−0·5	−1·0	−1·3	−1·9
August, 1918 ...	+7·5	+7·1	+5·6	+3·5	+1·5	−0·1	−0·8	−0·5	−0·7	−1·4	−1·3	−1·1

Mean Value for Month.

September, 1918.	August, 1919.	August, 1918.
14° 48′·6.	14° 40′·3.	14° 49′·0.

REMARKS.

The day is counted from 0h. (midnight) to 24h. (midnight), G.M.T.

Character "0" means a day wholly free from any but small disturbances.

" "1" " " part or all of which is moderately or considerably disturbed.

" "2" " " part or all of which is highly disturbed.

The normal value for an hour is the mean declination for that hour in the month, derived from quiet days only, or from all days excluding those of character "2." On a day of character "0" declination at any hour will usually be within about 3′ of the normal. On a day of character "1" the departure from the normal will usually not exceed 5′, but it may occasionally be as much as 10′, or even more. On a day of character "2" the departure from the normal will seldom exceed 20′, but departures of 30′, or even on extreme occasions of 1° or more, may occur.

The above values were obtained from measurements made after "smoothing" the curves.

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Explanations.

The — at the beginning of a line denotes the repetition of a word or word followed by a comma in the preceding entry; and in the case of Names, it includes both the Christian Name and the Surname; or, in the case of the name of any Firm, Association, or Institution, the full name of such Firm, etc.

Discussions are printed in *italics*.

The following contractions are used:—

M. C.—The Midland Counties Institution of Engineers.
M. G.—The Manchester Geological and Mining Society.
M. I.—The Midland Institute of Mining, Civil, and Mechanical Engineers.
N. E.—The North of England Institute of Mining and Mechanical Engineers.
N. S.—The North Staffordshire Institute of Mining Engineers.
S. I.—The Mining Institute of Scotland.
S. S.—The South Staffordshire and Warwickshire Institute of Mining Engineers.

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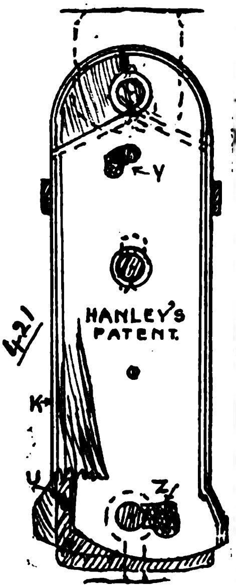

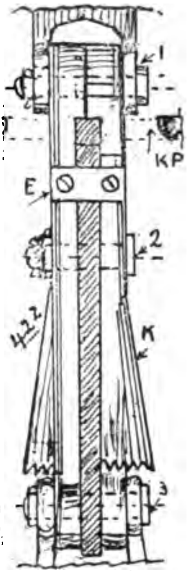

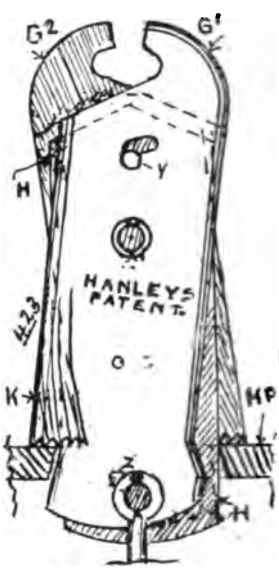

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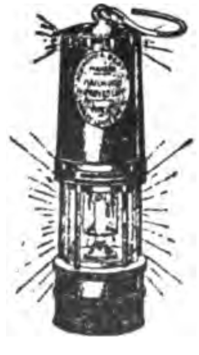

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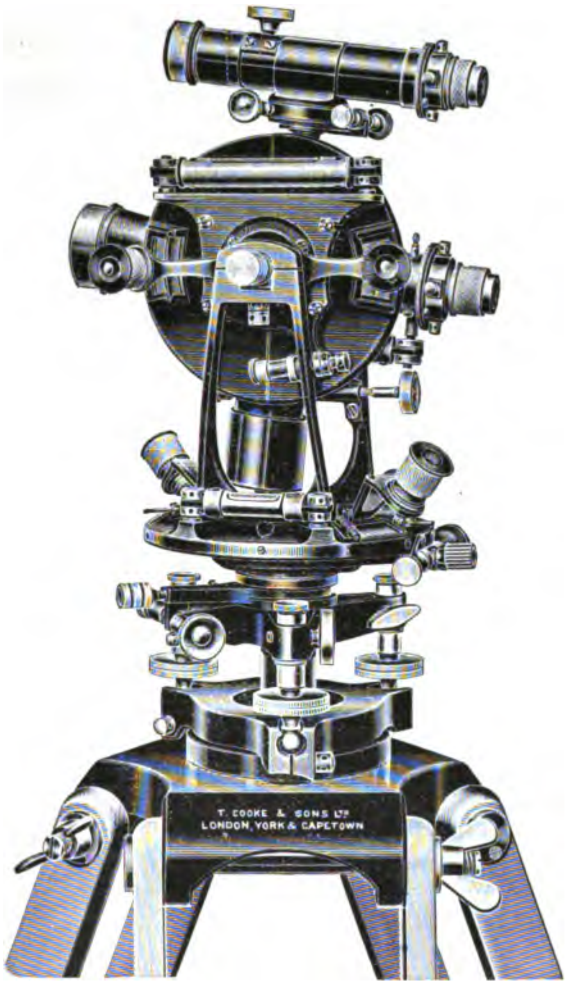
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Important Notice to Employers and Ex-Officers and Men of Higher Education.

The Appointments Department of the Ministry of Labour has for its main function to safeguard, direct, and assist the careers of demobilised officers and men of higher education—men qualified for the great professions and the middle and higher ranks of business life. Civilians with business and professional qualifications are also registered for appointments, but for the present its work is chiefly concerned with the ex-soldier.

There is little need to dilate on the difficulty and complexity of this great problem of reconstruction. Before it can be considered settled, hundreds of thousands of highly educated men will require to have been reinstated or launched for the first time into suitable, congenial, and sufficiently remunerative employment.

Some of these men are fully trained and ready to accept a post at once. They were in good positions before the war; they expect to obtain such on demobilisation. Others were in process of training when the war claimed them. These require to be "finished" before they can take their right place in the world. Others are quite "raw," and require to be trained from the beginning.

The Department deals with both *Appointments* and *Training*. The problem of placing the fully-trained man cannot be solved by the Department alone. It can interview such men, find out their qualifications and ambitions, and help them with advice and information, but it cannot invariably ensure their employment. It can catalogue the supply, but it cannot create the demand. It must rely on the Employer for that.

The Department realises fully the difficulties which face employers at this time. They were once free, and they will be free again; but for the time being they are in the chains of a myriad controls which hamper and exasperate them.

It cannot expect to obtain very great assistance from the Employers till they are free once more. Meanwhile it does all it can to interest and inform them. It can show them the men on its lists and arrange direct and speedy interviews, but it can do little more. It, therefore, appeals to every Employer who has or expects to have a post to offer to study its lists of men immediately available, and it promises to do all in its power to help them to quick and satisfactory decisions.

For the men who require training the Department can be of more direct assistance. It has divided this function with the Boards of Agriculture and Education. The former naturally superintends the training of men for agricultural pursuits, the Board of Education directs training in Universities and Colleges, whilst the Appointments Department arranges for the training of men in offices and works. *But all training candidates are registered first with the Department.*

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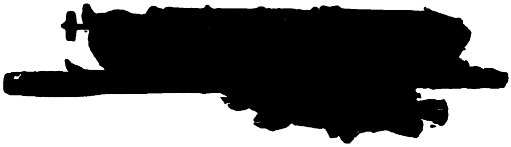

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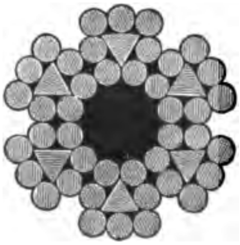

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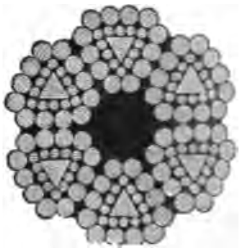

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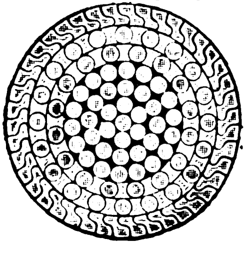

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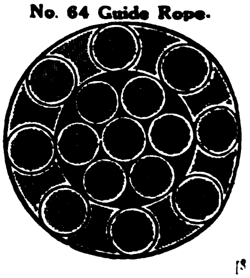

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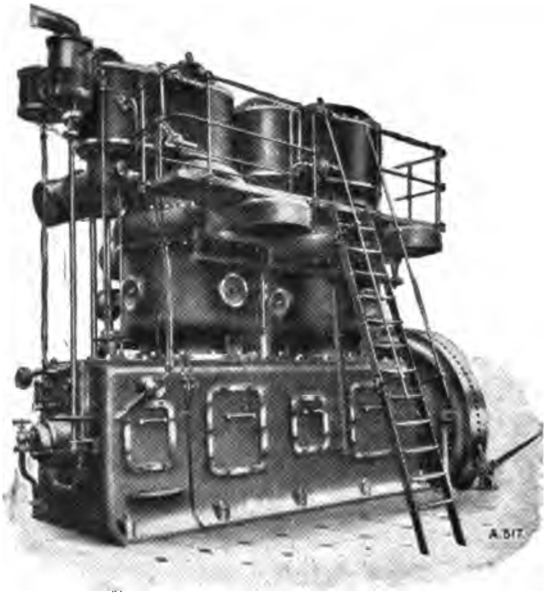

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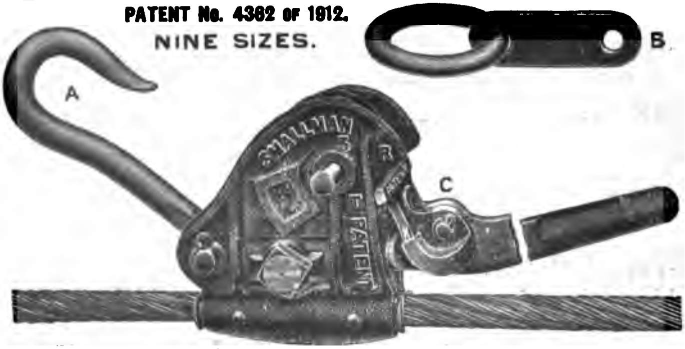

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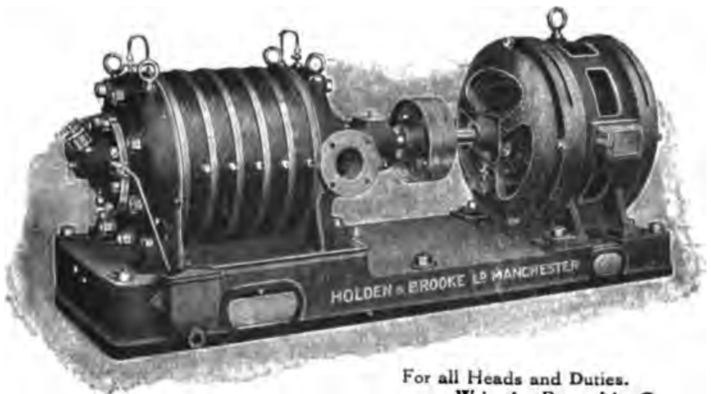

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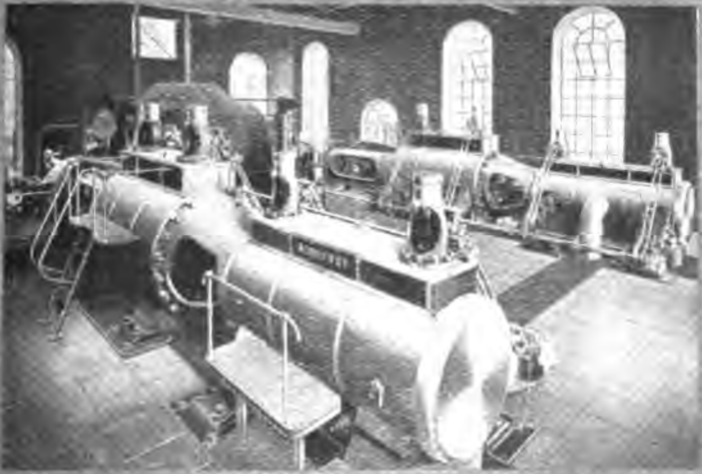

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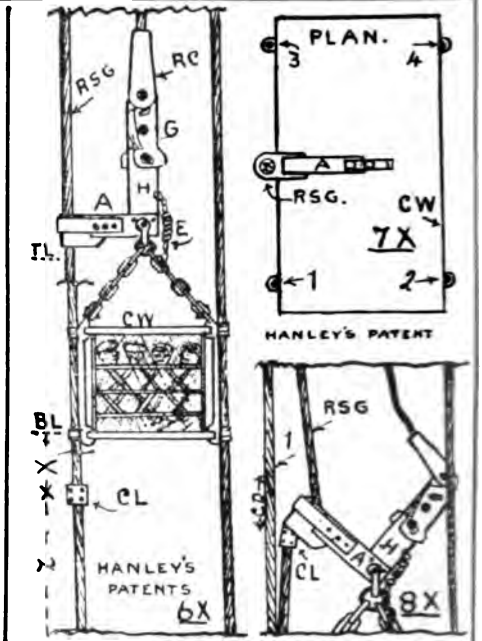

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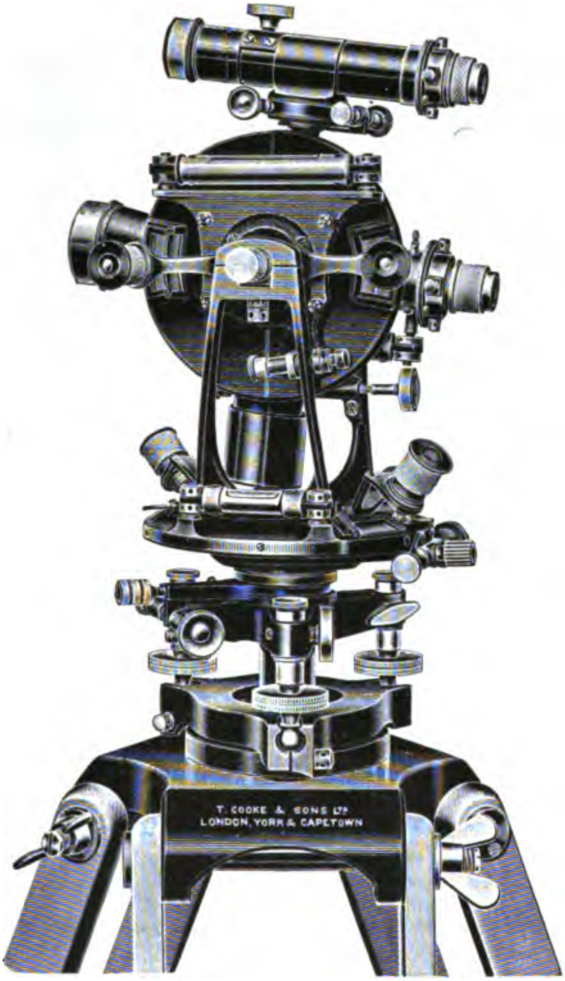
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The Council, in their Circular issued in January, 1919, summarized the steps taken by them in their efforts to obtain certain concessions on behalf of mining students serving with the colours who are desirous of sitting for their First Class Certificate of Competency under the Coal Mines Act on their return from active service, and stated that it had been officially held that only those candidates who, *before such service, have had the three years' practical experience* referred to in paragraph 1 of the Statutory Rules and Orders, 1917, Nos. 126 and 1,351, would be allowed to take advantage of the modifications made in the Rules on their behalf.

As a result of further representations to the Board for Mining Examinations, the Council are pleased to state that the following letter has been received from the Secretary to the Board, from which it will be seen that the three years' service referred to may be wholly or partly pre-war service:—

June 10th, 1919.

"I am directed by the Chairman of the Board for Mining Examinations to acknowledge your letter to him of the 4th instant, and, in reply, to inform you that the request of your Institution was laid before the Members of the Board at their last meeting, and it was resolved that an authoritative statement should be published to the effect that the relief granted to War Service candidates by the Statutory Rules and Orders, 1917, No. 126, may be claimed by anyone who has had 3 years' practical experience in mining whether that experience be wholly or partly pre-war service, provided that the practical experience is in accordance with the above Rules.

W. W. WARE,
Secretary to the Board."

The "authoritative statement" referred to in the above communication appeared in the issue of the *Colliery Guardian* for July 11th, 1919, page 106.

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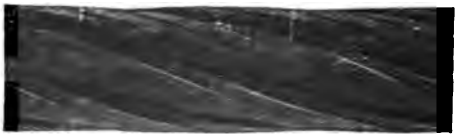

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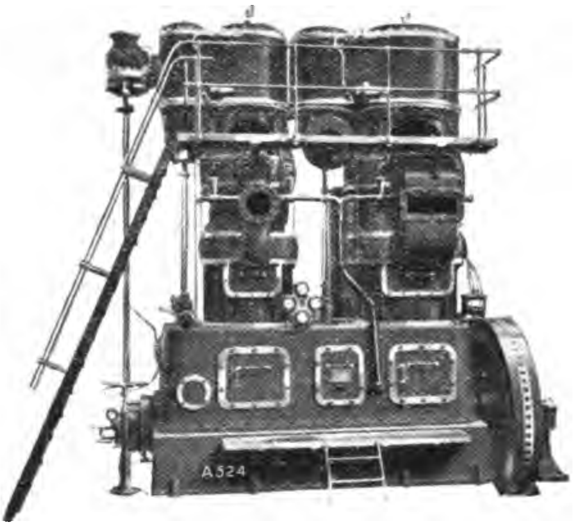

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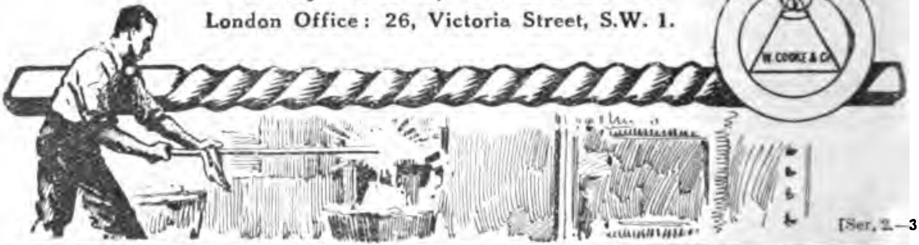

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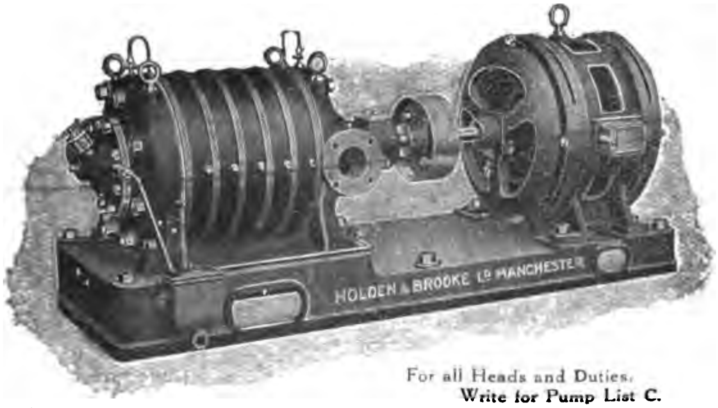

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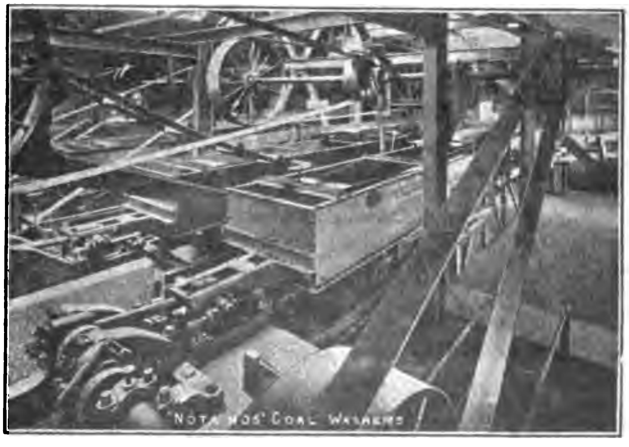

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